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الجامعة الأردنيـــة
كلية الدراسات العليا

التاريـــخ: ٣ / ١ / ٢٠١١

نموذج رقم (١٨)
اقرار والتزام بالمعايير الأخلاقية والأمانة العلمية
وقوانين الجامعة الأردنية وأنظمتها وتعليماتها
لطلبة الماجستير

أنا الطالب: محمد علي حسين الصمادي الرقم الجامعي: (٨٠٨١٥٤٨)

تخصص: هندسة النقل الكليـــــة: الهندسة والتكنولوجيا

عنوان الرسالة:

Suitability of using SUPERPAVE Technology in Jordan

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير عندما قمت شخصيا" باعداد رسالتي وذلك بما ينسجم مع الأمانة العلمية وكافة المعايير الأخلاقية المتعارف عليها في كتابة الرسائل العلمية. كما أنني أعلن بأن رسالتي هذه غير منقولة أو مستلة من رسائل أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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SUITABILITY OF USING SUPERPAVE TECHNOLOGY IN JORDAN

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This Thesis was Submitted in Partial Fulfillment of the Requirements for the Master's Degree of Science in Civil Engineering

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COMMITTEE DECISION

This Thesis (Suitability of Using SUPERPAVE Technology in Jordan) was successfully defended and approved on December, 2010.

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ABBREVIATIONS

%AC	Percent of Asphalt Concrete in the Mix
ASTM	American Society for Testing and Materials
CAA	coarse aggregate angularity
DSR	dynamic shear rheometer
ESAL	Equivalent Single Axel Loads
FAA	fine aggregate angularity
FHWA	Federal Highway Administration
FM	Fineness Modulus
G_{mb}	Bulk specific gravity of the Mix
G_{mm}	Maximum theoretical Specific Gravity of the Mix
G_{sb}	Bulk specific gravity of aggregate
HMA	Hot Mix Asphalt
JMF	Job Mix Formula
MPWH	Ministry of Public Works and Housing
NMAS	Nominal Maximum Aggregate Size
PG	Performance Grade of the bitumen
PMA	Polymer Modified Asphalt
QAIA	Queen Alia International Airport
RTFO	rolling thin-film oven
RV	rotational viscosity
SHRP	Strategic Highway Research Program
SUPERPAVE	SUperior PERformance asphalt PAVEments
WVDOH	West Virginia Division of Highways

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SUITABILITY OF USING SUPERPAVE TECHNOLOGY IN JORDAN

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ABSTRACT

This study aims to determine the suitability of adopting the SUPERPAVE Technology in Jordan, so that Jordan can keep up with the latest asphalt technology worldwide. This study evaluates the pavement structure changes during the design lifetime through quantification of aggregate degradation. The current Marshall design method and the proposed SUPERPAVE technology were compared in terms of their ability to predict pavement structure changes due to exposure to traffic loads throughout the design lifetime.

The aggregate degradation for the Marshall Hummer and Gyratory compactor were evaluated and compared with field degradation through utilizing four different methods, which were: the percent change in filler (materials passing sieve No. 200), the percent change in fine aggregate (materials passing sieve No. 4 and retained on sieve No. 200), the percent change in surface area of aggregate particles and the percent change in fineness modulus of aggregate.

It was noticed that degradation increased dramatically with field compaction, and that a five-year old asphalt pavement section experienced aggregate degradation that was not predicted by Marshall compaction. On the other hand, the gyratory compactor better simulated the field compaction. Both, the field and the gyratory compactor resulted in a major increase in the filler percentages with no significant increase in the fine aggregate percentages. Marshall compaction on the contrary, resulted in a major increase in the fine aggregate percentages with no significant increase in the fillers in wearing course but with remarkable increase in fillers in binder course. Approaching the upper limit of the specification was immediately after construction and prior to trafficking.

Local aggregates (limestone) experienced severe degradation due to the traffic loads (compaction). This leads in the course of time to an increase in the surface area and a reduction in the air voids. Accordingly, a new design method needs to be

adopted locally that can better simulate aggregate degradation and the change in the air voids which may lead to a better estimate of bitumen content. In order to prevent such degradation the use of Superpave in Jordan is presented as a new technology which addresses such needs.

A comparison of results on experimental section constructed by Ministry of Public Works and Housing using SUPERPAVE technology indicated that there was no significant difference in the optimum bitumen content when using basalt aggregate while the major differences were founded in the required percent air void directly after field compaction. More and better quality assurance measures were introduced by SUPERPAVE technology in controlling bitumen performance grade, degree of compaction and asphalt performance tests.

I. INTRODUCTION

Asphalt mixes consist of bitumen, aggregates and air voids. Proper proportioning will contribute into a good pavement structure and therefore. The asphaltic concrete that is adopted to be used within the road paving process is expected to meet a number of expectations such as [14]:

1. The stability to withstand the deformation caused by the traffic loads.
2. Impervious in order to prevent the leaking of water down to the lower layers of the road structure, but at the same time allow extra compaction under the traffic load through the air voids.
3. Durability in terms of resistance to the weather changes effects and the abrasion caused by traffic.
4. Provide a surface, which is skid-resistance.
5. Strengthen the road structure.
6. Provide sufficient workability to permit efficient placement.

The well-graded aggregate is commonly used in asphalt concrete mixes in the road construction and paving processes. In some countries, such as South Africa and the United Kingdom, Semi-gap graded or Gap-graded is being used in the process of asphalt construction. [15]

One of the major changes in the asphalt pavement is the aggregate degradation. This happens due to mixing, handling, compaction and trafficking. Aggregate degradation can impact the overall performance of the asphalt pavement structure; in

addition, it may alternate the volumetric properties of the mixture's design. So, as a result, the proposed compaction method during the design phase will have the ability to predict and simulate the degree of degradations.

This impact is considered to be more remarkable in the SUPERPAVE mixture design speaking form the fact that the specifications of aggregates have a leading role in the results of the final mix design [5]. The SUPERPAVE gyratory compactor was designed to simulate the degradation of aggregate within the production, mixing process, field compaction and trafficking [6]. The preset compaction energy by the Marshall hummer is predicted to provide levels of compaction which is considered to be similar to those provided by rollers within pavement construction processes.

Due to the defects of the Marshall mix design procedure, SUperior PERformance asphalt PAVEments (SUPERPAVE) technology was the outcome of six-year efforts accomplished by the Strategic Highway Research Program (SHRP) in the United States of America [11]. In Jordan, it is expected that the SUPERPAVE mix design will have a high potential of implementation in the coming future. Many steps were taken toward this direction, and in order to join all efforts together, the Ministry of Public Works and Housing (MPWH) in Jordan announced in 2010 the establishment of the Asphalt Technology Committee carrying the initiatives mission to introduce and implement new technologies in asphalt and highway construction in Jordan.

This study's main objectives are:

- To specify the compaction method that better simulates field densification and aggregate degradation through quantifying the resulting aggregate degradation from the SUPERPAVE Gyratory Compactor (SGC) and the Marshall Hummer and then compare the results with field samples' degradation.

- To compare optimum bituminous content needed according to the Marshall and SUPERPAVE methods using two types of local aggregates, which are Limestone and Basalt.

- To monitor the performance of SUPERPAVE and Marshall pavements, which are exposed to the same prevailing conditions by constructing experimental trial section.

This study is presented in chapters as follows:

Chapter-I: Introduction introduces the needs for a new Hot Mix Asphalt (HMA) Technology that can result in a durable pavement structure and can also predict the pavement behaviors during the service design life of the road through introducing the SUPERPAVE Gyratory Compactor (SGC), which can better simulate field densification due to construction and trafficking.

Chapter-II: Literature Review summarizes the related literature, which compared between SUPERPAVE Technology and Marshall mix design procedure. This was done to avoid unnecessary duplication of research and to concentrate on non covered areas as the ability of SGC to simulate field degradation using local aggregates.

Chapter-III: Evaluation of Degradation discusses the experiment done for an arterial highway in Amman city by quantification of five year asphalt pavement section degradation and compares results with laboratory compacted specimens using both SGC and Marshall Hummer.

Chapter-IV: SUPERPAVE Experiment summarizes the SUPERPAVE design procedure for 19-mm Basalt mix wearing course and compare the results with Marshall results for same aggregate gradation that conform to both design methods criteria. The mix design was implemented in Queen Alia International Airport Road (QAIAR) as a trial section that would provide long term monitoring of asphalt pavement performance comparison evaluation.

Chapter-V: Conclusions and Recommendations address the requirements to fully switch from the used Marshall Design procedure to the SUPERPAVE technology. Also summarize the results, findings of the study. It also discusses the continuous steps and the recommendations in order to successfully implement this new technology in Jordan.

II. LITERATURE REVIEW

The Marshall mix design method was adopted in Jordan so as to be used for asphaltic concrete mixtures design even though it has been dropped from the AASHTO procedures in 1998 and substituted by the SUPERPAVE technology [11]. Many studies have been conducted in order to examine the suitability of SUPERPAVE technology under local conditions and to evaluate the performance of SUPERPAVE mixes compared to Marshall Mixes as:

- "Quantification of Aggregate Degradation of Asphalt Mixes compacted by GYRATORY and MARSHALL methods" [14],
- "Performance evaluation of SUPERPAVE and Marshall asphalt mix designs to suite Jordan climate and traffic conditions" [11],
- "Volumetric Analysis-Based Comparison between Superpave and Marshall Mix Design Procedures" [3],
- "Overview on Local Experience in Asphalt Pavements" [1],
- "Comparison of 19 mm SUPERPAVE and MARSHALL Base II Mixes in West Virginia" [12].
- "Study on relationships of lab HMA compacting numbers between Marshall and SUPERPAVE" [17]
- "Comparative evaluation of laboratory compaction devices based on their ability to produce mixtures with engineering properties similar to those produces in the field" [16]

In this study, the comparison between SUPERPAVE technology and Marshall method was built in terms of their ability to simulate field aggregate degradation. Also trial section of SUPERPAVE will be constructed to check the suitability of using SUPERPAVE technology in Jordan.

The following paragraphs are a summary of the previous studies concerning this issue:

Malkawi et al. [14] compared between the SUPERPAVE Gyratory Compactor (SGC) and the Marshall Hummer in terms of the resulting aggregate degradation in the compacted specimens. The study targeted an evaluation tendency concerning the aggregate degradation for the Marshall and gyratory compaction methods. There were three various methods utilized in order to conduct such evaluation, which were: The percent increase in surface area of aggregate particles, the percent increase in fine aggregate and the percent increase in filler. At the time of the study (2002), particularly in Saudi Arabia, the SUPERPAVE mixture design had a high potential implementation, in addition, it was found out that the gyratory compaction method resulted in a lower degradation than the Marshall compaction method for wearing course mixes, while the Marshall compaction method gave lower aggregate degradation for the base course mixes. The difference between the Saudi study and this study is the use of field compacted samples as the base-line for the comparison between the two compaction methods. Nowadays, Saudi Arabia has adopted the SUPERPAVE technology in Ministry of Communications (MOC) specifications.

Asi [11] presented an evaluation of the performance of the SUPERPAVE and Marshall mix designs. Also an inclusive evaluation of the available local materials (asphalt binder and limestone aggregate) was carried out in the study in order to guarantee that all of these materials suit the new mix design procedures, which were

enhanced by SUPERPAVE. For the first time, a performance grading map was generated for Jordan as clarified in Figure 1.

Patterns from both mixes were prepared in the design asphaltic contents and aggregate gradations and undergone an inclusive mechanical evaluation examining. These examinations included Loss of Marshall Stability, Marshall Stability, Indirect Tensile Strength, Loss of Indirect Tensile Strength, Fatigue Life, Resilient Modulus, Creep and Rutting. In all performed examinations in the study, the SUPERPAVE mixtures proved to be superior over Marshall Mixtures. The Author recommended shifting from Marshall Mix design method to SUPERPAVE Technology.

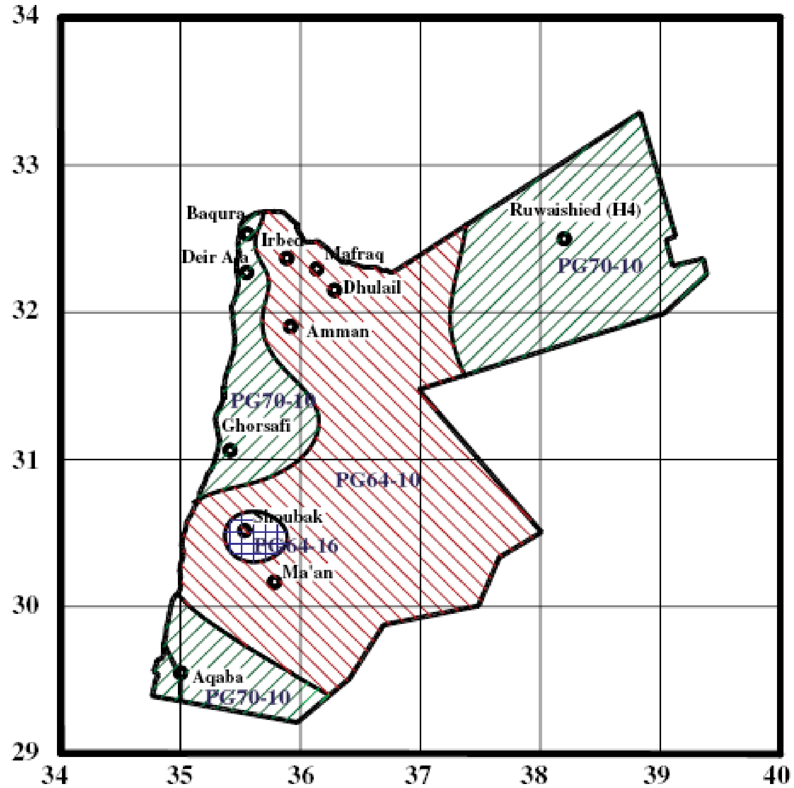

Figure 1[1]: Temperature zoning for asphalt binder specifications for Jordan [5]

1. I. M. Asi, "Performance evaluation of SUPERPAVE and Marshall asphalt mix designs to suite Jordan climate and traffic conditions", Construction and Building Materials Journal (CBMJ), Vol. 21,2007, pp. 1122-1128.

Khateeb et al. [3] conducted a study to compare between SUPERPAVE technology and Marshall mix design procedure in terms of volumetric analysis. Local materials were used in this study; namely limestone aggregates and 60/70 binder. One aggregate gradation conforming to both SUPERPAVE and Marshall criteria was used. The limestone aggregate tests included: coarse aggregate angularity (CAA), flat and elongated (F&E) particles, fine aggregate angularity (FAA), and sand equivalent (SE) test, as well as the SUPERPAVE asphalt binder tests including: rotational viscosity (RV), dynamic shear rheometer (DSR), and rolling thin-film oven (RTFO) test. The authors conclude that there was no significant difference the between optimum binder content obtained from Marshall mix design method and that using SUPERPAVE technology for the same aggregate gradation that conform to both design criteria

John et al. [5] conducted a research comparing Base II Marshall Design mixes and the 19-mm Superpave in West Virginia (WV) as a supplementation of the information required for West Virginia Division of Highways (WVDOH) to come up with an applicable decision concerning the implementation of Superpave for low volume roads. The Superpave and Marshall methods were compared through preparing similar mix design with each method. The results of the study indicated the absence of sufficient evidences to trace any influential differences between the Superpave mix and the Marshall Design methods, these results need more investigation and therefore, further researches are needed as a comparison between Marshal Design method and SUPERPAVE technology.

Haitao ZHANG et al. [17] compare between the two Lab compaction methods; the Marshall hammer impact compaction and SGC gyratory compaction. The relationships between Marshall hammer impact compacting numbers (Nm) and Superpave SGC gyratory compacting numbers (Ns) were divided into two parts for

research, based on the traffic volume (ESAL) standard and density (Gmb) standard as follow:

1. Based on the traffic volume (ESAL) standard, through the test research in China and Japan, the relationships of Lab HMA compacting numbers (Nm,Ns) between Superpave and Marshall were established, i.e. Marshall for 2×75 vs. Superpave 100.

2. Based on the HMA density (Gmb) standard, through the test research in China and Japan, the relationships of Lab HMA compacting numbers (Nm,Ns) between Superpave and Marshall were established, i.e. Marshall for 2×75 vs. Superpave 60-75 (60 for coarse aggregate and 75 for fine aggregate)

Through the analysis on the three relationships of the compaction numbers between Marshall and Superpave, and based on the development of the traffic volume in the world, the paper suggested that the Marshall compaction standard should be increased. The following research conclusions have been put forwarded according to the research:

1. The test results indicated that Marshall compact standard was lower than Superpave, it was not fit the heavy traffic volume today and should be increased or replaced by Superpave standard.

2. There were no big differences about the HMA volumetric performance between Marshall and Superpave based on the same density (Gmb) standards, therefore, it depends on the HMA mechanics performance whether Marshall should be replaced by Superpave or not, this will be researched further.

3. Based on the same density standard and same volumetric performance, Marshall method should be replaced by Superpave if the HMA mechanics performance was increased.

Von Quintus et al. [16] conduct a study to check if laboratory-molded mixtures were fabricated in a manner that will adequately simulate field conditions and, consequently, yield reliable engineering properties. Their study described a field and laboratory study that evaluates the ability of five compaction devices as a simulation of the field compaction. The evaluated compaction devices were selected in accordance with their uniqueness and availability in mechanical manipulation of the mixture, in addition to the potentiality for usage by the agencies which are responsible for asphaltic mixture design. The evaluated devices were (a) the Texas gyratory compactor, (b) the mobile steel wheel simulator, (c) the Marshall Impact hammer, (d) the California kneading compactor and (e) the Arizona vibratory-kneading compactor. The ability of the five laboratory compaction devices to simulate field compaction was based on the similarities found between engineering properties (resilient modulus, indirect tensile strengths and strains at failure and tensile creep data) of laboratory-compacted samples and field cores. Five projects were selected for the sake of this study. The locations of the five mentioned projects were Colorado, Texas, Virginia, Michigan and Wyoming. The field compaction procedure used at the sites was the standard procedure used by the state highway departments responsible for the highways involved. In general, the gyratory compactor of Texas clarified the possibility to provide mixtures with engineering properties nearest to those determined from field cores. The kneading compactor of California and the mobile steel wheel simulator came in the second and third rank, respectively, but with very small differences between the two. The vibratory-kneading compactor of Arizona and

the Marshall Impact hammer ranked as the least effective in terms of their ability to produce mixtures with engineering properties similar to those from field cores.

III. Evaluation of Degradation

3. 1 TESTING PLAN

3.1.1 Materials

In this experiment, the limestone aggregate was collected from the same quarry used in preparing the HMA of QAIA road in 2004. The quarry is located in Maeen area. The asphalt used was 60/70 – penetration grade produce by Jordanian Refinery, and PG64-10 produced by RasTanura Refinery, Saudi Aramco. Sufficient materials were gathered to produce the needed laboratory samples. Two aggregate gradations were selected for this study that conform to both Marshall and SUPERPAVE criteria, one for the wearing course and one for the binder course as per the JMF produced by the Engineering Axis for Studies for Marshall Specification limits which happen to satisfy the 19-mm SUPEPAVE gradation limits.

1) Aggregates:

Figure 2 shows a picture of the quarry in Maeen and the cold bins where aggregate were collected from. Figures 3 & 4 represent the 0.45 power gradation chart for the wearing and binder course Job Mix Formula (JMF), respectively as per Marshall mixes, also specifications limits and restricted zone are indicated in the same chart.

(a) Crusher

(b) Cold bins

Figure 2: Picture of Maeen quarry

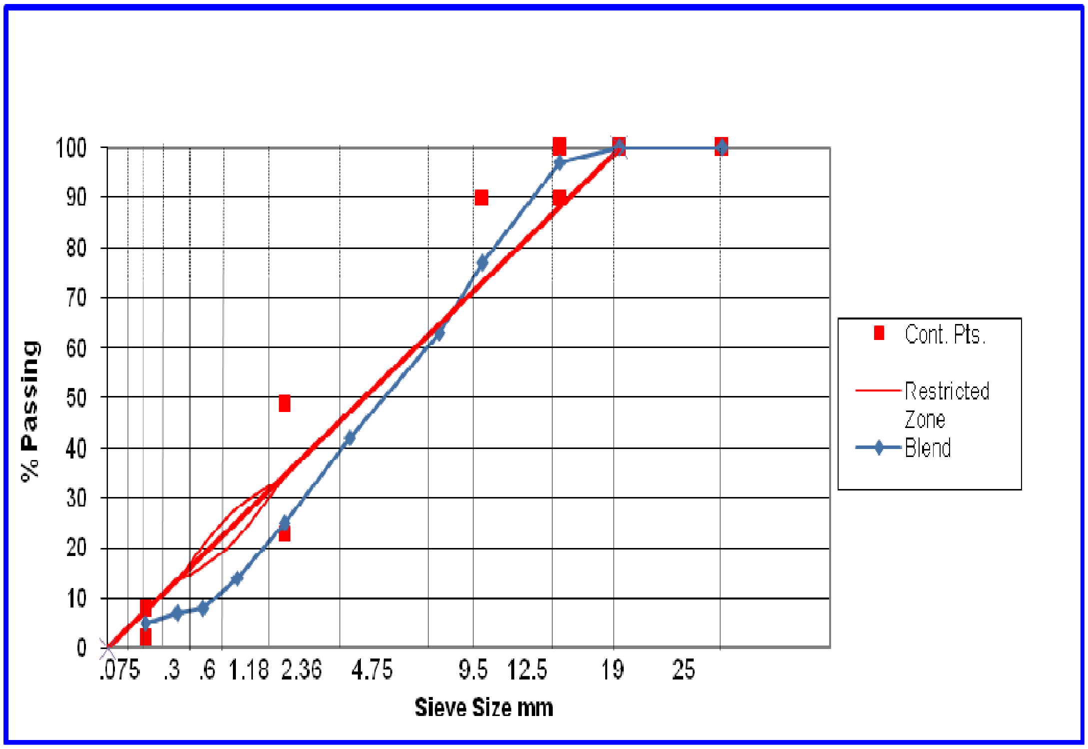

Figure 3: 0.45 power gradation chart for Wearing course

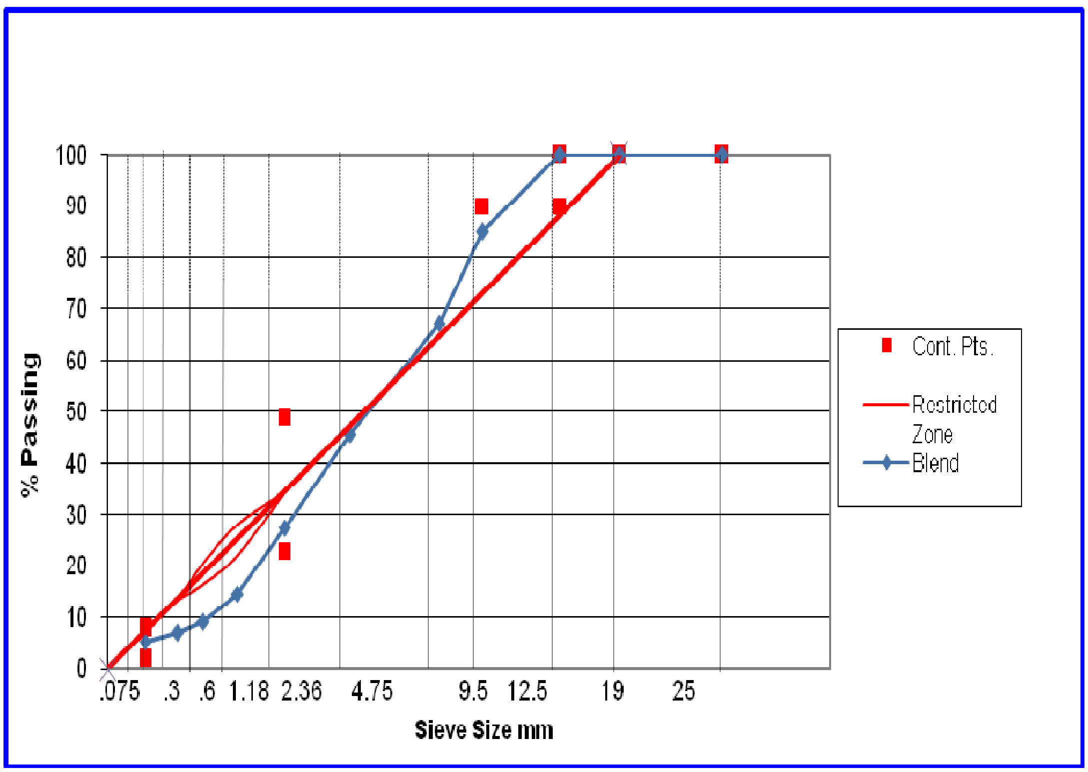

Figure 4: 0.45 power gradation chart for Binder course

2) *Asphalt Performance Grade:*

SUPERPAVE performance Graded (PG) binder system was developed during the SHRP and aimed to address the climatic effects of pavement temperatures. And to determine required PG for the project area, the following steps were adopted:

i) Identify the hottest seven-day period for each year.

ii) Calculate the standard deviation and the mean of the seven-day average maximum air temperature for all the years of operation for last 10 years.

iii) Identify the one-day minimum air temperature for each year.

iv) Calculate the mean and standard deviation of the average one-day minimum air temperature.

v) Convert the air temperature to pavement temperature.

vi) Select the reliability concerning the design pavement temperatures. Reliability is defined as the a single year percent probability in which the actual temperature (one-day low or seven-day average high) won't surpass the corresponding design temperatures.

Ten year daily temperature readings were collected from Meteorological Department for Amman Airport Highway and the required asphalt grade was determined to be PG64-10; results are shown in Table-1. This grade matches with the results by ASI [11].

Table 1: PG selection for QAIA at Latitude 32˚

Amman Airport		
Year*	Average max. 7-day air temp. (C˚)	Min. Air Temp. (C˚)
1999	36.50	1.10
2000	39.49	-1.20
2001	35.44	0.60
2002	37.33	-1.00
2003	34.36	0.20
2004	35.37	-2.10
2005	36.33	-0.50
2006	34.99	-1.10
2007	38.54	0.60
2008	36.91	-4.50
Average	36.53	-0.79
Standard Deviation	1.6071	1.6428
	High- ^{o}C	Cold- ^{o}C
T_{pave} (pavement Temp.)**	58.31	-0.79
Target(98% reliability)	61.53	-4.08
Choose	**64.00**	**-10.00**
Actual reliability	99.776%	99.99%

* Daily temperature were hidden for simplicity

** High air temperature is converted to pavement temperature (20-mm depth) using the following equation:

$$T_{20}=(T_{air}-0.00618Lat^2+0.2289Lat+42.2)(0.9545)-17.78$$

Figure 5: Picture for wearing and binder field slabs at right carriageway

3.1.2 Field Samples

The portion of QAIA highway from station 2+000 to 2+200 was constructed in April 2004. During the preparing of this research (May 2009) the same portion was closed for traffic to construct a new interchange.

A representative asphalt slabs (about 60X60cm) as shown in Figure 5 were collected for the binder and wearing layers from different lanes on both directions.

3.1.3 Sample Preparation

Aggregates were collected from the cold bins in the asphalt plant. It was decided to accurately duplicate the mix that was used in the field during the construction process. Therefore, the collected aggregates were tested and compared with original aggregate tests to ensure same source of aggregates was used, with similar properties, namely, abrasion, and specific gravity as shown in Table-2.

Table 2: Aggregate Tests

JMF	Test	Original Aggregate used for construction	Collected Aggregate used for research
Wearing Course	Abrasion	33%	33.56%
	Gsb	2.492	2.486
Binder Course	Abrasion	33%	33.56
	Gsb	2.49	2.486

The gathered aggregates were classified on the basis of the sieve sizes in JMF. Six samples of aggregate blend were prepared for both Marshall binder course and wearing course, while twelve samples of aggregate blend were produced for both SUPERPAVE binder course and wearing course as shown in Figure 6. The mixing and preparation and of the samples were done in accordance with ASTM D1559.

Marshall Samples were prepared with the specified optimum asphalt content as per the original Marshall JMF; SUPERPAVE samples were prepared at three asphalt contents:

a. Same as Marshall JMF (expected bitumen content)

b. According to Superpave mix design criteria

   - ½ % above expected bitumen content
   - ½ % bellow expected bitume content

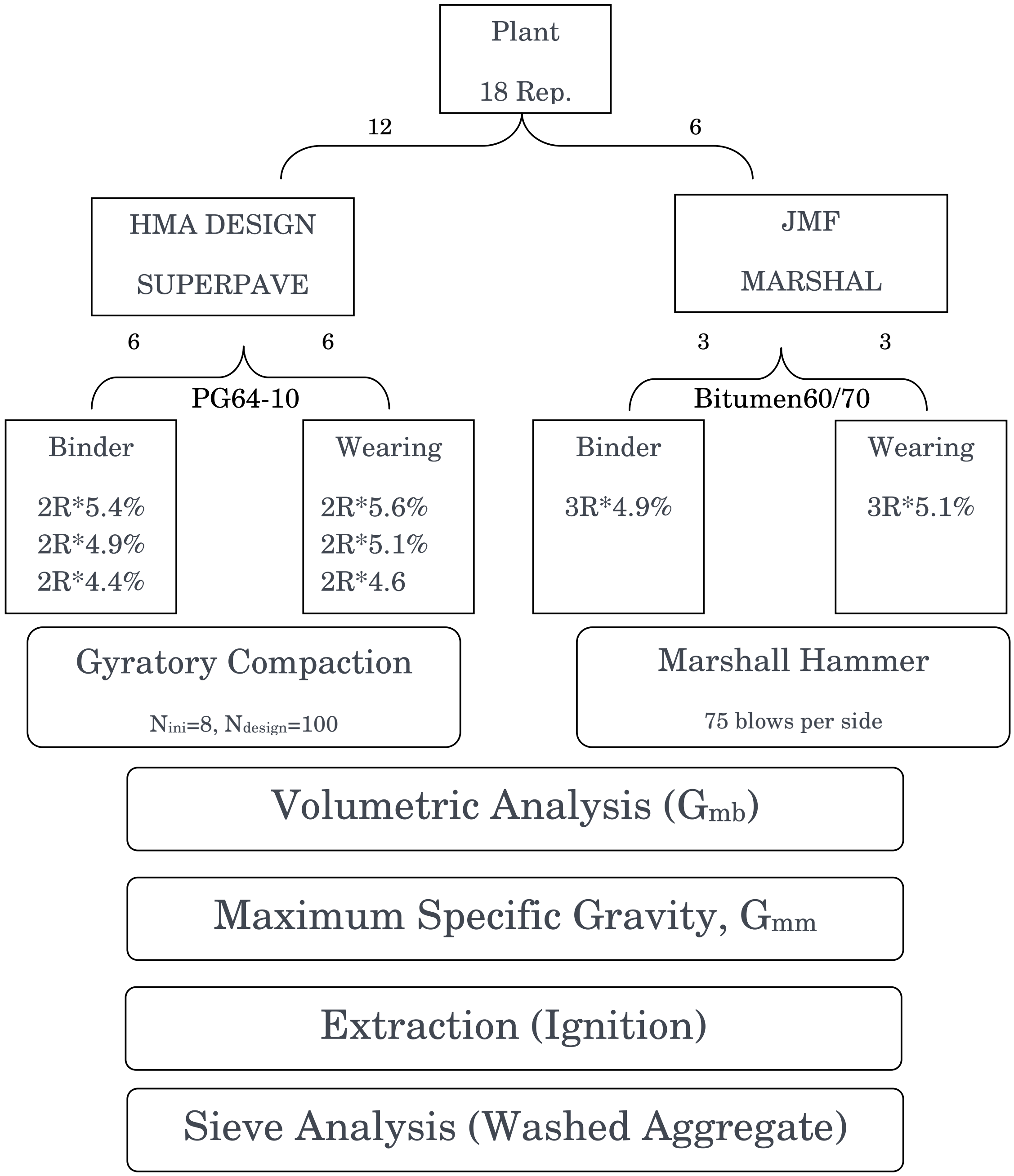

Figure 6: Work Plan

3.1.4 Compaction Methods

The gyratory and Marshall compactors that were used in this study are shown in Figure 7. For Marshall Compaction method:

1. The aggregates were placed in the oven for overnight at 160°C (mixing temperature),

2. Mixing tools and asphalt bitumen were placed in oven at 160°C for two hours prior mixing, and

3. During the blending process, the loose mixture was heated in an oven at a temperature of 150°C (compaction temperature) for one hour in order to simulate the short-term aging during the blending and lay down condition. After that,

4. Using an automatic Marshall Hammer with 75 blows per side the 100mm diameter samples were compacted.

The ASTM D1559 standard was followed here. Three samples of binder course and three samples of wearing course were prepared using the compaction method.

(a) *(b)*

Figure 7: (a) SUPERPAVE Gyratory Compactor (SGC) and (b) Marshall Hammer Compactor.

For the gyratory compaction, the gyrations' design number (N_{design}) was determined from the calculated expected level of traffic on the design lane through 20-year period of time without taking into account the actual design life of the road-way. Traffic volumes and classification were adopted from Consolidated Consultants in 2005 [7] without modifications since year 2005 was the opening year of the project. The Equivalent Single Axel Loads (ESAL) was calculated on the basis of the (FHWA) vehicle classification as shown in Table 3.

Table 3: Equivalent Single Axel Load (ESAL) Calculation [2]

AADT	60,662	**Vehicle Classification**	Design Life (YRS)	20
Growth	4.0%		Corrected (n)	29.78

Class	**Type**	**Description**	**Typical ESALs per Vehicle***	**AADT**	**ESALs**
2	Passenger Cars	All coupes, station wagons and sedans manufactured primarily in order to carrying passengers and including those passenger cars pulling recreational or other light trailers.	negligible	39553	0
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All vehicles, four tire and two-axle vehicles other than passenger cars. Included in this classification are panels, vans, pickups and other vehicles like campers, ambulances, motor homes, hearses and carryalls. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.	negligible	16239	0
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) which function as passenger-carrying vehicles. All two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified.	0.57	2532	14909622
5	Two-Axle, Six-Tire, Single Unit Trucks	All vehicles on a single frame including motor homes, trucks and camping and recreational vehicles which have two axles and dual rear wheels.	0.26	1452	3899462
6	Three-Axle Single Unit Trucks	All single-framed vehicles including trucks, camping and recreational vehicles, motor homes which have three axles.	0.42	473	2051990
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles.	0.42	205	889340
9	Five-Axle Single Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.	1.2	208	2578157
					24,323,335

[2] Federal Highway Association (FHWA), 2001

Table 4: Lane distribution ESLAs

Location	Lane distribution Factor	million ESAL's @5 year	million ESAL's @20 year
Right Carriageway **(Rt-CW)**	70%	3.10	17.03
Left Carriageway **(Lt-CW)**	20%	0.89	4.87
Right Shoulder **(SH'd)**	10%	0.44	2.43

The design ESALs for 5 years and 20 years were determined as shown in Table-4, the total expected ESALs along 20 years is 24.323 million ESALs, then for 70% the share of lane distribution for right carriageway as per AASHTO, expected ESALs are $0.7*24.323=17.03*10^6$. Therefore N_{design} value of 100 was selected for this study and $N_{initial}$ value of 8 was selected too according to AASHTO.

The following compaction process was followed in this study [4]:

1. Post mixing, the loose mixture was heated in an oven at a temperature of 150°C for a couple of hours in order to simulate the short-term aging during the mixing and compaction condition. Throughout this process, the asphaltic mix was stirred every one hour to ensure uniform aging.

2. The base-plate and the compaction molds (150-mm diameter) were heated in the oven at the temperature of 150°C for one hour prior usage.

3. The vertical pressure of the gyratory compactor was set at 600 KPa.

4. The N_{design} was set to 100 gyrations.

Figure 8: SUPERPAVE compacted specimen

5. The inclination angle of 1.25˚ was applied, and

6. The compaction process stops automatically when reaching the design number of gyrations (100).

The previously mentioned procedure was applied on twelve samples (six binders and six wearing) as shown in Figure 8.

3.1.5 Aggregate Testing for Degradation

Bulk specific gravity was calculated for all compacted samples in accordance with ASTM D2726 in addition; percent air voids were also calculated. Two samples from Marshall compacted specimens (one binder and one wearing) were selected for determination of maximum specific gravity using Corelok device. The other four samples were used to extract the asphalt from the mix by ignition and reclaiming the aggregate in accordance with ASTM D2172 procedure. Each of the twelve SUPERPAVE samples were divided into two equal portions using quartering, one portion was selected for determining the maximum specific gravity while the other was subjected to extraction and reclaiming of the aggregate.

The reclaimed aggregates from extraction were sieved again using the same set of sieves. Figure 9 shows the used instruments for sieving, extraction and Gmm calculations.

Figure 9: Extraction, Gmm and Sieve analysis

3. 2 Calculations & results:

Table 5 shows the calculated surface area, fineness modulus, percentage of fine aggregate and the percentage of filler material. Appendix A shows all calculation for aggregate degradation. Also Figures 11, 12, 13 & 14 show the relation between each parameter and the expected ESALs.

Figure 10 shows the road typical cross section. The construction consisted of adding a new carriageway with 3 meters paved shoulder, and 5 cm wearing course overlay on the entire carriageway width.

Table 5: Binder and wearing course Degradation

BINDER COURSE	**JMF** ESALs =*0*	**Marshall** ESALs $_{exp.}$=*0.1*	**Field Shoulder** 0.44 mEASLs	**Field Rt. carriageway** 3.10 mEASLs	**SUPERPAVE** 17.03 mEASLs $_{exp.}$
Total Surface Area(cm^2/gm)*	65.68	85.24	87.23	88.6	131.75
Fineness Modulus (FM)**	4.04	3.92	3.88	3.83	3.59
Fine Aggregate %	36.90	38.01	39.35	40.71	43.14
Filler %	5.10	6.98	7.15	7.14	11.86
WEARING COURSE	**JMF** ESALs =*0*	**Marshall** ESALs $_{exp.}$=*0.1*	**Field Lt. carriageway**	**Field Rt. carriageway** **3.10 mEASLs**	**SUPERPAVE** 17.03 mEASLs $_{exp.}$
Total Surface Area(cm^2/gm)*	70.13	75.19	90.40	89.05	152.13
Fineness Modulus (FM)	3.96	3.90	3.83	3.78	3.45
Fine Aggregate %	40.10	41.28	40.77	42.81	44.59
Filler %	5.50	5.68	7.24	6.94	13.88

* Surface area factors (cm^2/gm) for each sieve was adopted from Subramanyam and Pratapa [11]

** FM= (Σ Cumulative percent retained)/100; for fine aggregates i.e. passing No. 4 and retained on No.200

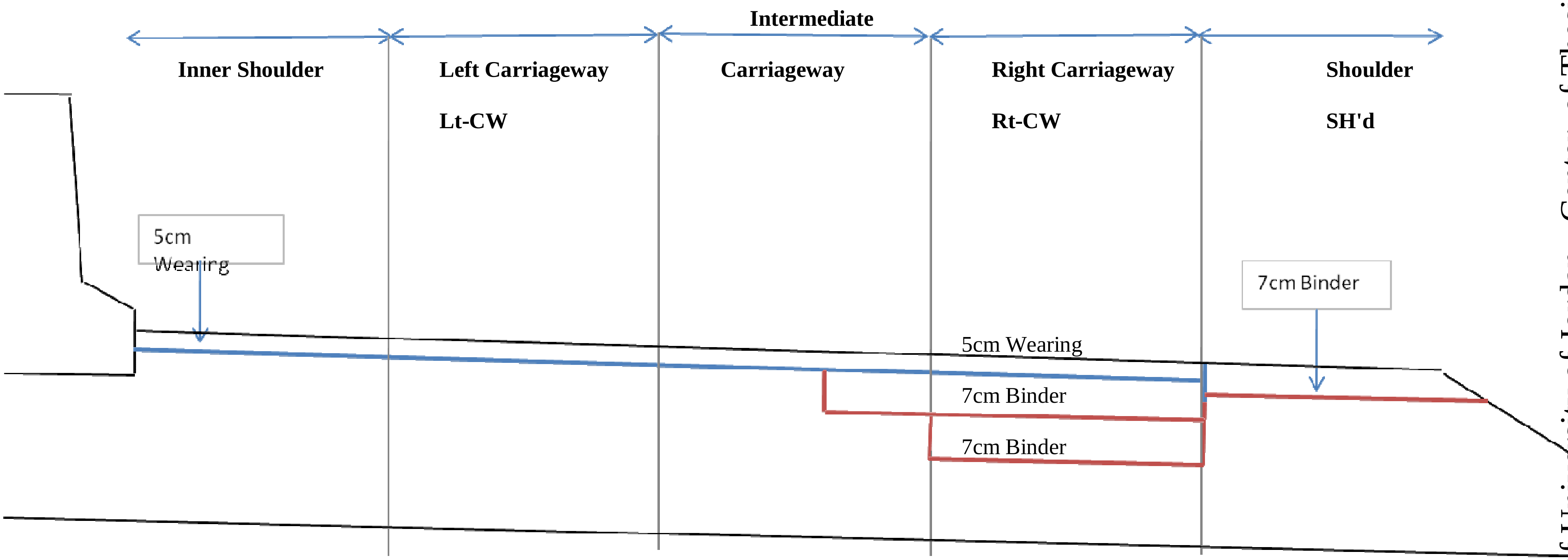

Figure 10: Typical Cross Section for QAIA Road Widening

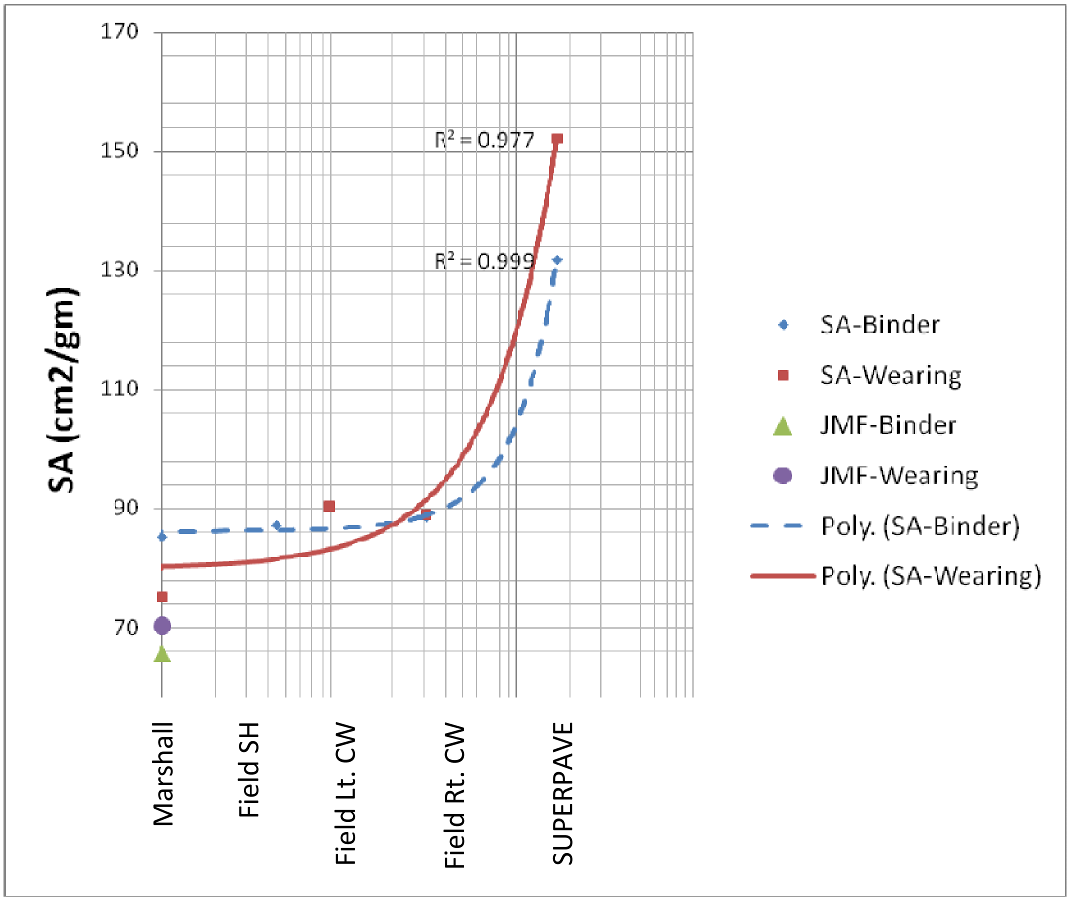

Figure 11: Surface Area

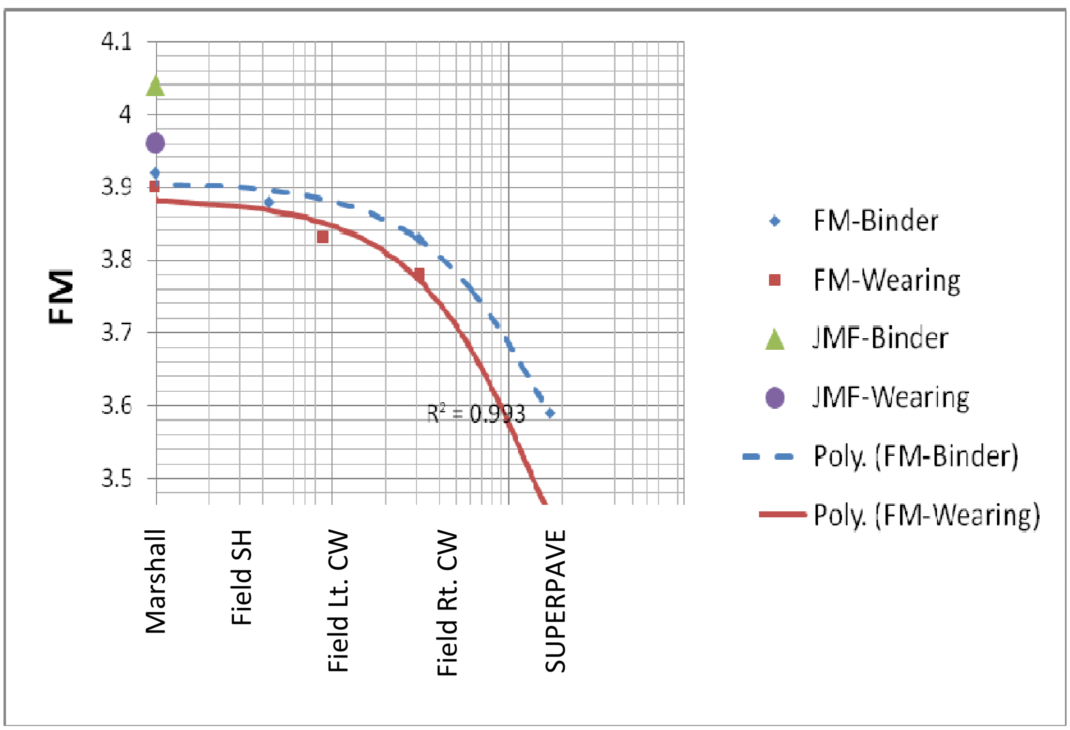

Figure 12: Fineness Modulus

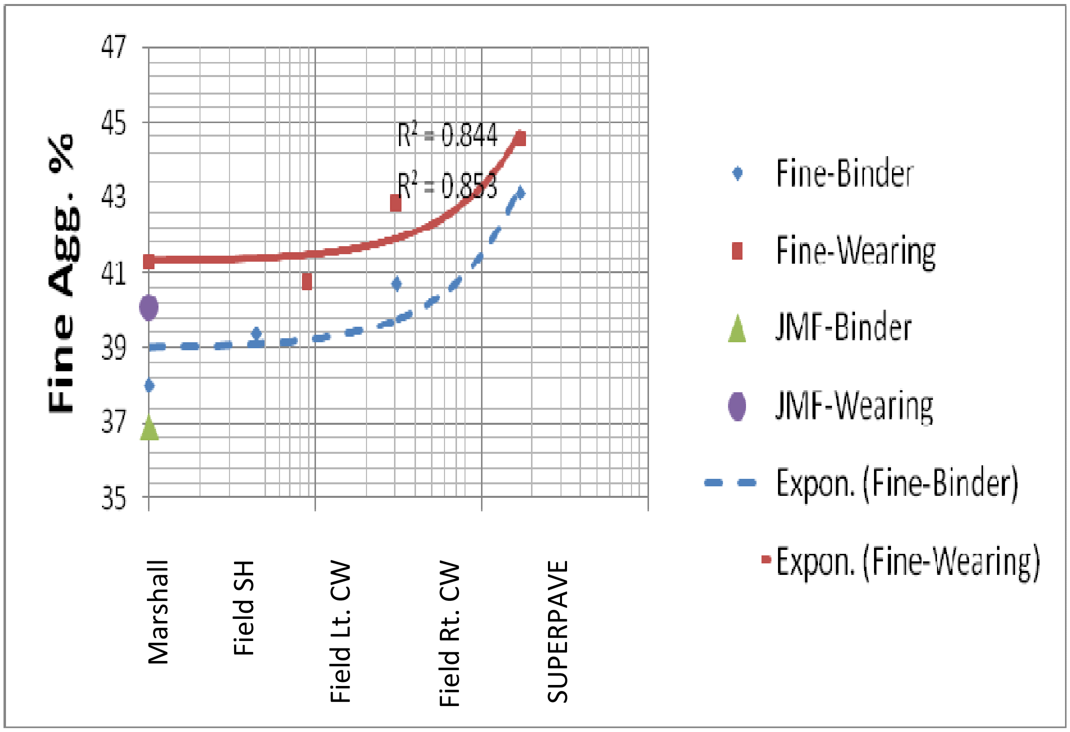

Figure 13: Fine Aggregate Percentage

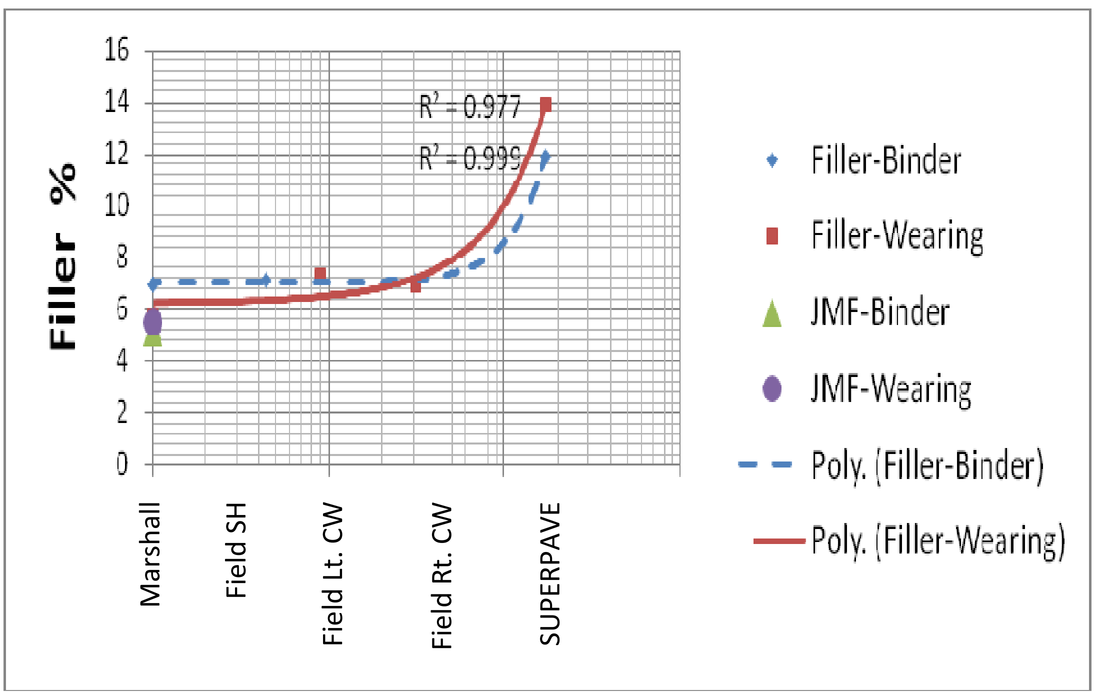

Figure 14: Filler material percentage

3. 3 Data Analysis

3.3.1 *GENERAL*

Table-5 is a clear evidence of the significant increase in aggregate degradation with trafficking, and that five-year old field asphalt slabs suffer from degradation that was not predicted by Marshall compaction, while gyratory compaction better simulated the field compaction.

For the wearing course aggregate, gyratory compaction resulted in major increase in filler percentages with minor increase in fine aggregate percentages, while Marshall compaction showed minor increase in both fine aggregate percentages and fillers percentages. Marshall samples showed significant increase in fine aggregate and filler percentages approaching the upper limit of the specification immediately after construction and prior to trafficking (passing No. 200 =6.98% for binder course, upper limit=8%).

3.3.2 *PERCENT OF FILLER*

For wearing course, the percent of filler materials passing sieve No. 200 increased from 5.5% for JMF to 5.68%, 6.94% and 13.88% for Marshall, field & SUPERPAVE densification, respectively. This was taken as evidence that the Marshall compaction simulates the construction compaction, field sample is 25% of roadway design life time, and SUPERPAVE simulates the total densification due to trafficking along the pavement design life.

For binder course, the percent of filler increased from 5.1% for JMF to 6.98%, 7.14% and 11.86% for Marshal, field & SUPERPAVE densification, respectively. This reads the same as for the wearing course but with remarkable high value for the

Marshall compaction. The higher content of fillers is not recommended within the asphalt mix since it makes it prone to rutting problems [14].

3.3.3 FINE AGGREGATE PERCENTAGE

The percent of the aggregate passing No.4 and retained on sieve No. 200 (fine aggregates) were calculated and the results showed that for wearing course they increased from 40.10% for JMF to 41.28%, 42.81% and 44.59% for Marshall, field & SUPERPAVE densification, respectively. This could explain the minor increase in filler for Marshall, since at the initial conditions the course aggregate suffered from degradation that resulted in noticeable increase in fine aggregate percentages; with time (Trafficking) this extra percentages in fine aggregate would be subjected to further degradation that would increase the filler percentage. Same analysis applies for binder course.

3.3.4 PERCENT CHANGE IN SURFACE AREA AND FINENESS MODULUS.

It is evident that the wearing course aggregate proved to be finer than the binder course aggregate, the surface area for wearing was 70.13 cm^2 and for binder: 65.68 cm^2), and the fineness modulus (FM) for wearing was 3.96 and for binder 4.04, the higher the FM the coarser the aggregate. The purpose of including the FM in comparison is to exclude the impact of fillers from evaluating the aggregate degradations.

Such high increase in the surface area proves the need for better method to design for the asphalt binder content in the mix in order to provide a coat for the aggregate particles to guarantee the necessary adhesion to the whole mix and consequently the sufficient strength of the pavement.

3.3.5 OPTIMUM BITUMEN CONTENT

To get global comparison between the two compaction methods, monitoring the optimum bitumen content is required. Therefore, and as stated before; additional SUPERPAVE samples were prepared at ±0.5% bitumen content.

As shown in Figure 15 for the wearing course, the extra effort by gyratory compactor *_to simulate field trafficking_* resulted in less air void for the same bitumen content than Marshall Hammer; the same observations from Figure 16 for binder course can be concluded by the shift down in the SUPERPAVE curve. Therefore, optimum binder content at 4% air void ($OBC_{4\%}$) for SUPERPAVE wearing is 4.84% which is lower than Marshall $OBC_{5\%}$ (5.1%). In addition for SUPERPAVE binder, $OBC_{4\%}$ is 4.72% which is lower than Marshall $OBC_{5.5\%}$ (4.90%).

Results show that SUPERPAVE design required less bitumen content than Marshall Method for the same limestone aggregate gradation that conform to both SUPERPAVE and Marshall criteria. However, it should be noted that the same gradation was used in this study to facilitate the comparison. Once the SUPERPAVE has been officially adopted, one can come-up with even a better (optimum) aggregate structure.

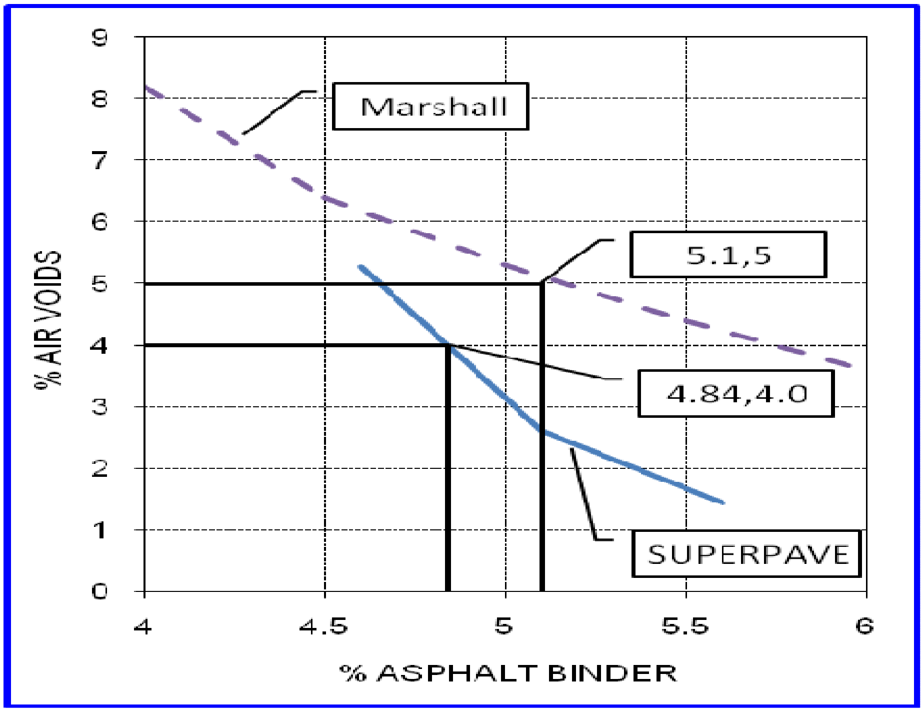

Figure 15: Air voids Vs Binder content curve for Wearing Course

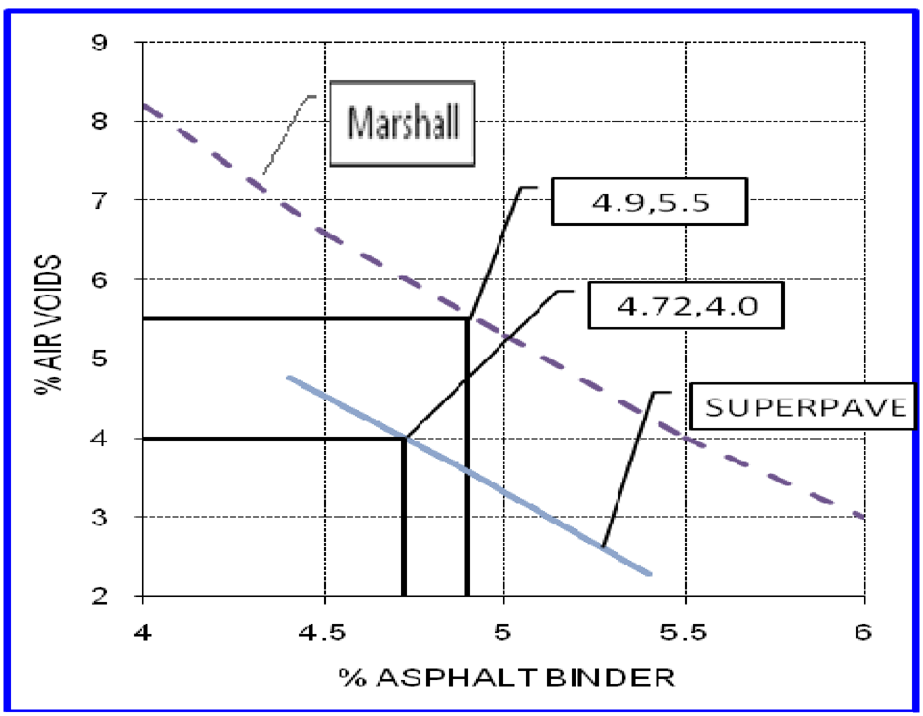

Figure 16: Air voids Vs Binder content curve for Binder Course

IV. SUPERPAVE Experimental Section

4.1 INTRODUCTION

Asphalt pavement is a mixture of aggregate with optimum amount of bitumen to coat the aggregate particles and to provide the necessary adhesion and the sufficient strength to the pavement structure. So, as it is clarified, the asphaltic concrete gets its strength mainly from the mastic cohesion and aggregate interlock [14].

The Asphalt Technology Committee (ATC) at MPWH started reviewing the drawbacks in the currently used Marshall design method. It also reviewed the advantages of using Basalt aggregate over limestone. ATC decided to establish multi trial section on the new projects in order to enhance the local experience in the new technology.

As part of efforts taken to implement SUPERPAVE in Jordan as well as other asphalt technologies, three trial experimental sections were built as part of Queen Alia International Airport Highway project. These sections will be monitored during trafficking and thereafter compared to each other evaluation.

The project consists of reconstruction of existing QAIA road from Naoor Interchange to the Airport Interchange; it consists of three sections:

a) Basalt Using Marshall Design

b) Basalt using SUPERPAVE design (0+080 → 0+600)

c) Basalt using EE2 Polymer Modified Asphalt (PMA) and Marshall

MPWH (the owner of the project), Dar Al-Handasa (the designer) and General Equipment Cont. Co. (the contractor of section C) all cooperated to ensure the success

of this experimental section. The first trial section will be constructed at the permanent part of the detour.

The project special specifications required the use of Basalt aggregate in the wearing course for the service roads and the main road. Messer Engineering Axis was responsible producing the Marshall mix design in accordance with MPWH specification [13].

4.2 TESTING PLAN

4.2.1 Materials

The aggregate which was used in this study was collected from the contractor's batch plant that was approved to be used in preparing the HMA of this project. The Basalt aggregates used in this study were mixed with fine limestone; the asphalt binder was 60/70 penetration grade produce by Jordanian Refinery, which happens to satisfy the PG64-10 requirement as tested by Jordan University of Science and Technology laboratories [3].

Sufficient quantities were collected from hot bins to produce the required laboratory samples. One aggregate gradation as per the JMF produced for Marshall Specification limits which happen to satisfy the 19.0 mm SUPEPAVE gradation limits. Aggregate gradation chart is shown in Figure 17; also Table 6 shows the aggregate blend analysis.

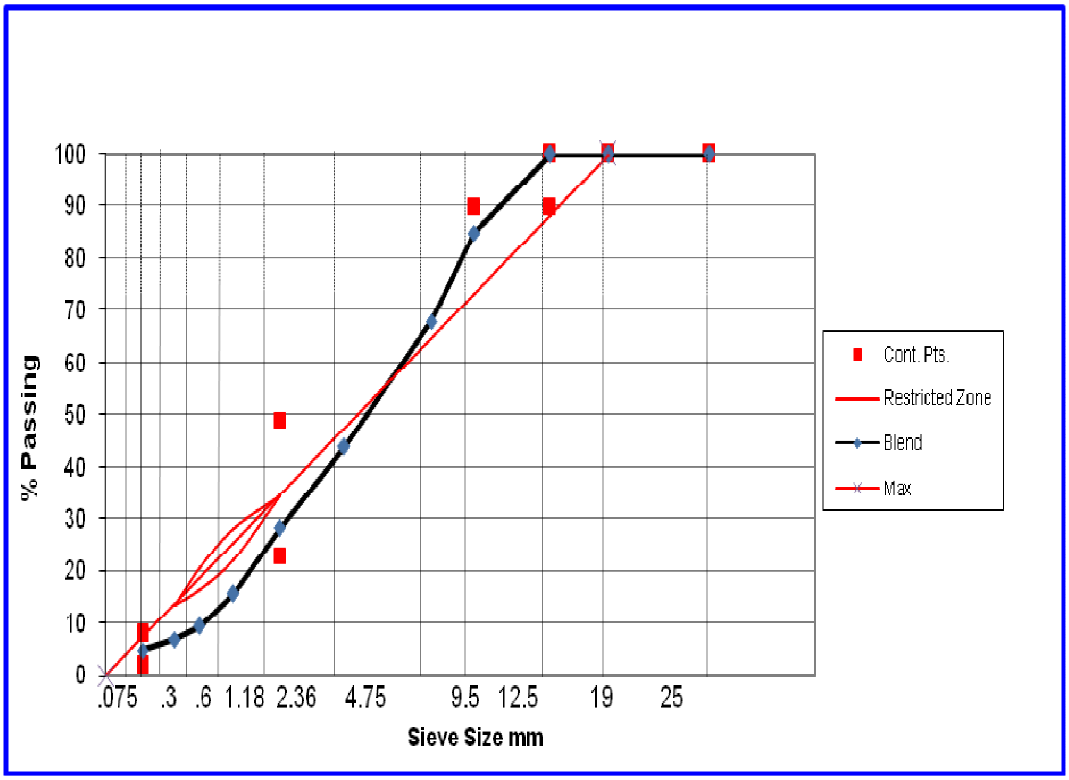

Figure 17: 0.45 power gradation chart for Basalt Wearing course

Table 6: Aggregate blend analysis

Aggregate Blend Analysis

Project:	QAIA Road	Spec.	ASTM	Date:	12-Mar-10
Location:	Airport Road	TH#:	50 mm		
Mix Type:	19mm Superpave	BASALT WEARING COURSE			

	%	Aggregate Description	Legal Description
1	29	#1 Coarse Agg. (Basalt)	Hot Bin No.1
2	36	#2 Medium Agg. (Basalt)	Hot Bin No.2
3	35	#3 Fine Agg. (Mixed: Basalt + Lime)	Hot Bin No.3

Aggregate		1	2	3	4	5	6			
%Aggregate		29	36	35						
Sieve Size (mm)		Percent Passing								
1	37.5	100	100	100					100.0	
1"	25	100	100	100					100.0	MAS
3/4"	19	100	100	100				NMAS	100.0	
1/2"	12.5	48	100	100					84.9	
3/8"	9.5	9	84	100					67.9	
#4	4.75	3	23	99					43.8	
#8	2.36	2	5	74					28.3	
#20	1.18	1	2	42					15.7	
#50	0.6	1	2	24					9.4	
#80	0.3	1	2	17					7.0	
#20	0.075	0.6	1.7	11.4					4.8	
	Gsb	2.798	2.782	2.687					2.753	

AC Content:	**4.643%**	NMAS	**19.0**
Asphalt Source:	Jor. Refinery	Grade:	**PG 64-10**

- *Asphalt Performance Grade:*

Ten year daily temperature readings were collected from Meteorological Department for Amman Airport Highway, and the required asphalt grade was PG 64-10 as shown previously in Table-1.

4.2.2 Specifications

Tables 7, 8, 9 & 10 summarize SUPERPAVE AASHTO criteria that were used in this experiment.

Table 7: 19mm mix aggregate gradation SUPERPAVE control points

Sieve Size	Control Pts. Lower	Control Pts. upper	Res. Zone	
37.5	100	100		
25	100	100		
19	90	100		
12.5		90		
2.36	23	49	34.6	34.6
1.18			22.3	28.3
0.6			16.7	20.7
0.3			13.7	13.7
0.075	2	8		

Table 8: SUPERPAVE Criteria (AASHTO 2001)

Design Traffic Level (ESALs) Millions	**Compaction Parameters** N_{ini}	N_{design}	N_{max}
<0.3	6	50	75
0.3 to <3	7	75	115
3 to 30	**8**	**100**	**160**
30 +	9	125	205
Required Density (% Gmm)	< 91.5% (<0.1M ESALs) <90.5% (0.1 to <1M ESALs) <89.0% (>1M ESALs)	= 96.0%	≤ 98.0%

Table 9: SUPERPAVE specifications

Project Design Specifications			
20	**Design Traffic Load (ESALs x 10e6)**		
36.5	**7 Day Average High Temperature (C)**		
19.0	**Nominal Maximum Aggregate Size (mm)**		
8	**N-Initial**	13	**%VMA(Min)**
100	**N-Design**	65	**%VFA(Min)**
160	**N-Maximum**	75	**%VFA(Max)**

Table 10: SUPERPAVE volumetric[3]

20-yr Traffic Loading (millions ESALs)	**Minimum Sand Equivalent (%)**
< 0.3	40
0.3 to < 3	
3 to < 10	45
10 to < 30	
≥30	50

%VFA Look-Up Table		
ESALs	**Min**[3]	**Max**
<0.3	70	80[1]
0.3 to <3	65	78
3 to 10	**65**	**75**
10 to <30	65	75
>30	65[2]	75

Minimum %VMA Look-Up Table	
9.5mm	15.0
12.5mm	14.0
19.0mm	13.0
25.0mm	12.0
37.5mm	11.0

(1) For 25.0-mm NMS mixes, the Min VFA shall be 67% for design traffic levels <0.3 million.
(2) For 9.5-mm NMS mixes, the VFA range shall be 73% to 76% for 3 million + ESALs.
(3) For 37.5-mm NMS mixes, the Min VFA shall be 64% for all design traffic levels.

4.2.3 Sample Preparation

Like other mix design methods, the Superpave method generates many trials aggregate-asphalt binder trial blends, with different asphalt binder content for each. After that, through evaluating the trial blends, the optimum asphalt binder content is determined. As a way to accomplish this, the trial blends must contain an enough range of asphalt contents above and below the optimum asphalt content. Therefore, the first step in the

[3] Tables 7-8-9-10 American Association of State Highway Officials, AASHTO Specifications

process of the sample preparation is to determine approximate estimation of the optimum asphalt content. Trial blends asphalt content are then determined from this estimate.

Each aggregate sample is heated to reach the expected blending temperature for a short time (up to 4 hours) and then compacted with the gyratory compactor. Blending and compaction temperatures are selected based on the asphalt binder properties. Key parameters of the gyratory compactor are:

- Size of the sample= 150 mm (6-inch) diameter cylinder approximately 115 mm (4.5 inches) in height. Note that this sample size is larger than those used for the Hveem and Marshall Methods (see Figure 18).

Figure 18: Superpave Sample (left) vs. Hveem/Marshall Sample (right)

- Load = circular and Flat with a diameter of 149.5 mm (5.89 inches) corresponding to an area of 175.5 cm^2 (27.24 in^2), which can accommodate aggregate as larger as 38mm (1 ½ inch)

- Compaction pressure = Typically 600 kPa (87 psi)

- Gyrations' Number = N_{design} = 100

- Method of simulation = the load is applied to the sample top and covers at most the entire sample top area. The sample is inclined at 1.25˚ and rotates at 30 revolutions per minute as the load is continuously applied. This helps achieve a sample particle orientation that is somewhat like that achieved in the field after roller compaction.

Three different gyrations numbers are established by the Superpave gyratory compactor:

1. $N_{initial}$: The gyrations' number used as a measure of mixture compact-ability within construction. Mixes that compact too fast (air voids at $N_{initial}$ are too low) may be tender during construction and unstable when it is subjected to traffic. Usually, this is a good indicator of aggregate quality; HMA with excess natural sand will frequently fail the $N_{initial}$ requirement. A mixture designed for greater than or equal to 3 million ESALs with 4 percent air voids at N_{design} should have at least 11 percent air voids at $N_{initial}$ (Table-9).

2. N_{design}: This is the design gyrations' number required in order to produce a sample with as same density as that expected in the field after the expected amount of traffic. A mix with 4 percent air voids at N_{design} is targeted in mix design.

3. N_{max}: The gyrations' number required to produce a laboratory density that should never be exceeded in the field. If the air voids at N_{max} are too low, then the field mixture may compact excessively under traffic resulting in exceedingly low air voids and possible rutting. The air void content at N_{max} should never drop below 2 percent air voids (Table-9). Typically, samples are compacted to N_{design} in order to establish the optimum asphalt binder content and then additional samples are compacted to N_{max} as a check. Previously, samples were compacted to N_{max} and then $N_{initial}$ and N_{design} were back-calculated [5].

4.2.4 Test Results

The volumetric outcomes for the tested samples are shown in Table 11, where samples 1a, 1b & 1c represent three replicates for same bitumen content, and so for the other samples at four different bitumen content.

Table 11: Bulk specific gravity of the mix (Gmb)

Sample #	Gmb = (A / (B - C)) * K						
	Bitumen Content %AC	A	B	C	ºC	G_{mb}	Corr. G_{mb}
		Dry Mass	SSD Mass	Mass in H_20		(Ndes)	(Nini)
Sample 1a	3.5	4640.2	4685.1	2774.1	25	2.428	2.209
Sample 1b		4676.4	4727.8	2790.6	25	2.414	2.191
Sample 1c					25		
Sample 2a	4.0	4673.2	4700.8	2821.2	25	2.486	2.247
Sample 2b		4717.0	4744.9	2840.3	25	2.477	2.244
Sample 2c		4677.3	4732.6	2815.4	25	2.440	2.245
Sample 3a	4.5	4715.4	4729.7	2837.8	25	2.492	2.247
Sample 3b		4710.8	4734.4	2831.2	25	2.475	2.230
Sample 3c		4726.0	4742.8	2839.4	25	2.483	2.270
Sample 4a	5.0	4704.3	4710.2	2837.6	25	2.512	2.260
Sample 4b		Sample were not properly compacted					
Sample 4c		4725.9	4733.5	2839.8	25	2.496	2.277

Table 12:
Average Compaction (%Gmm) at different %AC

Cycles \ %AC	3.5	4.0	4.5	5.0
8.0	83.262	85.671	86.533	87.987
10.0	84.135	86.513	87.380	88.882
20.0	86.471	88.888	89.927	90.768
30.0	87.817	90.279	91.379	92.904
40.0	88.751	91.216	92.427	93.944
50.0	89.512	91.970	93.213	94.736
60.0	90.053	92.555	93.856	95.429
70.0	90.522	93.070	94.406	95.931
80.0	90.916	93.461	94.854	96.404
90.0	91.314	93.827	95.226	96.801
100.0	91.635	94.145	95.549	97.122

Table 13: Volumetric Properties at N_{design}

#	%AC	%Air Voids	%VMA	%VFA	Optimum Ac (%)
1	3.5	8.36	15.12	44.7	**4.643**
2	4.0	5.85	13.94	58.2	
3	4.5	4.45	13.84	67.9	
4	5.0	2.88	13.58	78.9	

The optimum asphalt binder content is selected so that asphalt binder content that results in 4 percent air voids at N_{design}. This asphalt content then must meet SUPERPAVE criteria namely [5]:

1. Air voids at $N_{initial} \geq 11$ percent (for design ESALs > 3 million).
2. Air voids at N_{max} > 2 percent.
3. %VMA ≥13 for NMAS of 19-mm
4. %VFA within the range (65-75) for 19-mm NMAS
5. Dust to Binder ratio (DP) within the range (0.6-1.2)

Figure 19 and 20 shows the resulting compaction chart and the volumetric charts. The optimum bitumen content at 4%AV is 4.643%. The other corresponding volumetric were determined and checked against SUPERPAVE criteria.

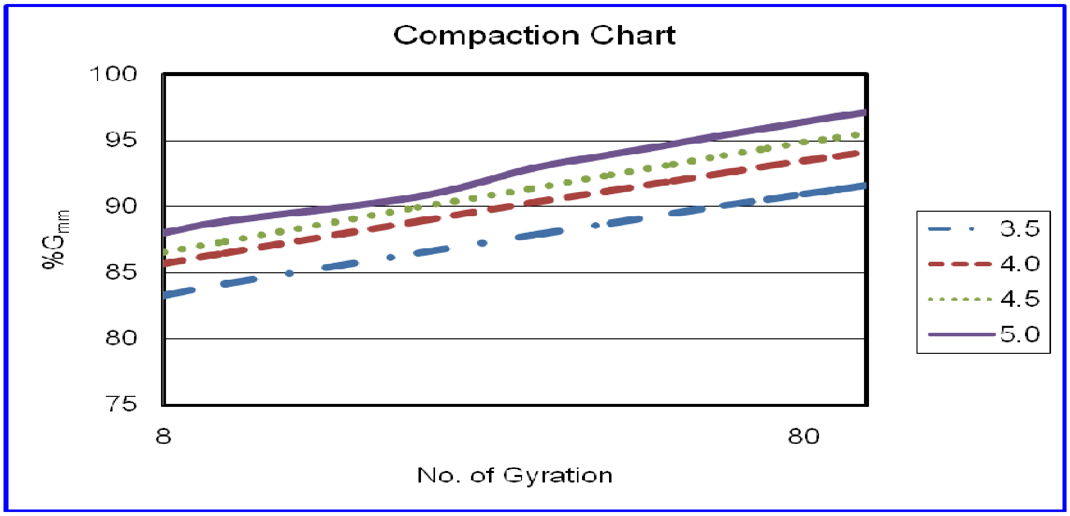

Figure 19: 19-mm SUPERPAVE Compaction Charts

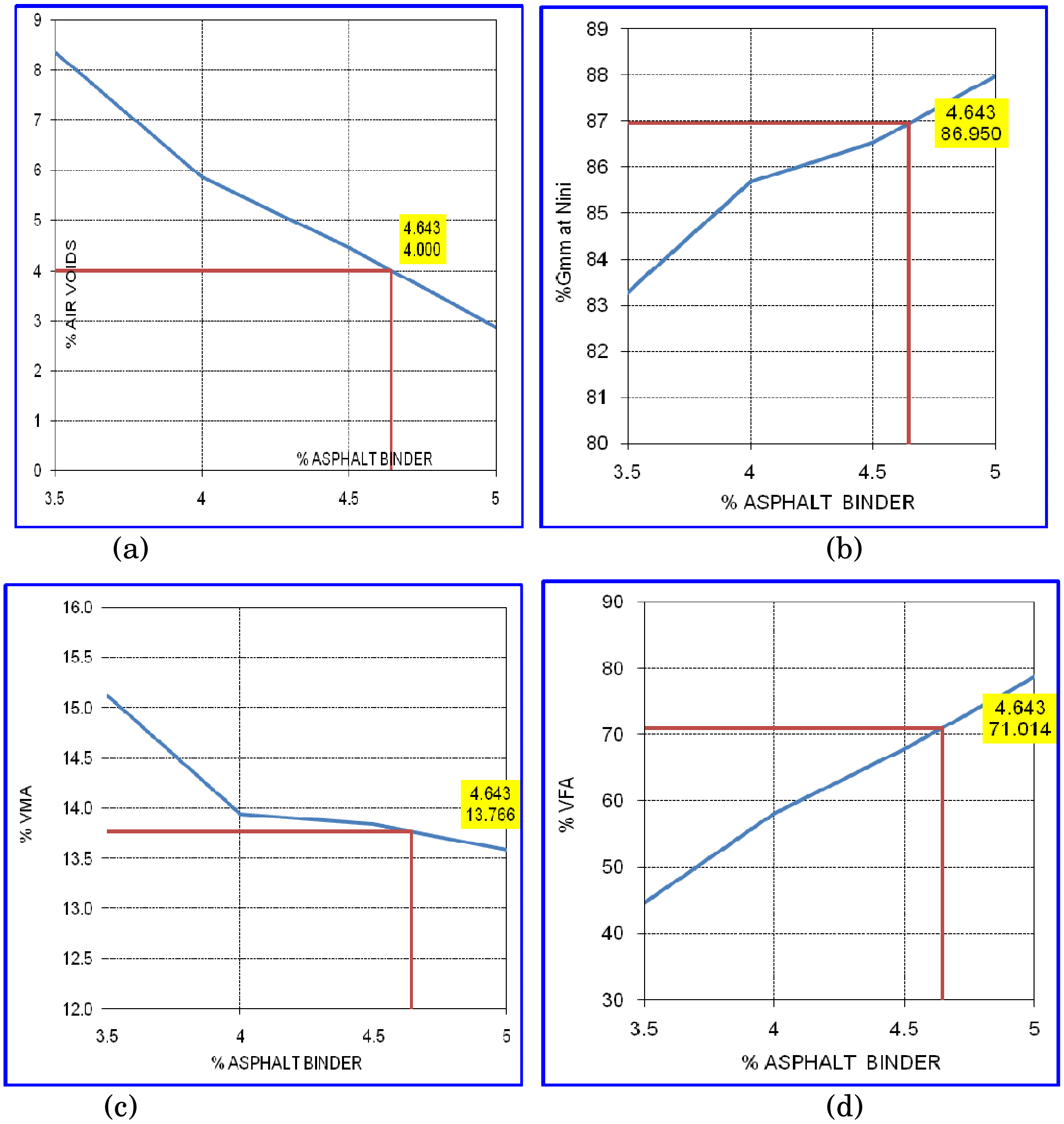

Figure 20: 19-mm SUPERPAVE Mix Design Volumetric charts

TABLE 14: HMA MIX DESIGN OUTPUT

HMA Component	**Weight (kg / Ton of mix)**	**%Wt**
Bitumen (PG 64-10)	46.50	4.65
Basalt Coarse Aggregate (Hot Bin 1)	276.5	27.64
Basalt Medium Aggregate (Hot Bin 2)	343.5	34.33
Mixed Fine Aggregate (Hot Bin 3)	334	33.38
Total	1000.5	100

4.2.5 Design Output

The given JMF with an optimum PG 64-10 bitumen content of **4.643%** and maximum specific gravity **Gmm=2.593** satisfy the requirement for 19mm SUPERPAVE HMA design criteria stated in AASHTO 2001.

The material proportions are summarized in Table 14 in terms of weight per one ton of mix. These proportions were used in the asphalt plant to produce the HMA that used for the SUPERPAVE trial section.

4.3 Comparison with Marshall

The resulting optimum bitumen content from SUPERPAVE Mix design (4.643%) was slightly higher than the output obtained from Marshall Method (4.45%). This result is different from the limestone experiment where SUPERPAVE resulted in less bitumen needs. However, this might refer to the high resistance to abrasion of Basalt aggregate so that extra compaction exposed by Gyratory compactor make no significant difference in aggregate structure, i.e., no more severe degradation, also considered an evidence for the impact of the changes in the mix volumetric due to aggregate degradation. Therefore, continues using local limestone aggregate required the implementation of SUPERPAVE technology.

4.4 Field Results

The specified initial air void by Engineering Axes (Marshall Mix) was 5% while the required percent G_{mm} after laying and compaction is 93%±1, i.e., the initial air void is from 6% to 8%. The contractor performed trial compaction patterns in order to ensure getting required densification for the trial section. Asphalt cores were taken from constructed trial sections for quality assurance purpose and results were accepted except

for core No.5 on the right detour. Tests were performed on May 2nd, 2010, and the results were tabulated in Tables 15 & 16.

TABLE 15: FIELD DENSITY AND ASPHALT THICKNESS – RIGHT DETOUR (SUPERPAVE)

SPECIMEN NO.	STATION K.M	THICKNESS (CM)	SPECIMEN BULK DENSITY (G / CM3)	THEORETICAL MAX. SPECIFIC GRAVITY (GMM)	% Gmm	Location
1	0+160	5.2	2.403	2.593	92.7	Rt.
2	0+240	6.3	2.392	2.593	92.3	CL.
3	0+320	5.8	2.419	2.593	93.3	Lt.
4	0+400	5.0	2.409	2.593	92.9	Rt.
5	0+480	5.5	2.377	2.593	**91.7**	CL.
6	0+560	5.2	2.418	2.593	93.3	Lt.
				Average	92.7	
				Coeff. Of Var.	0.00668	

TABLE 16: FIELD DENSITY AND ASPHALT THICKNESS – LEFT DETOUR (SUPERPAVE)

SPECIMEN NO.	STATION K.M	THICKNESS (CM)	SPECIMEN BULK DENSITY (G / CM3)	THEORETICAL MAX. SPECIFIC GRAVITY (GMM)	% Gmm	NOTE
1	0+160	5.2	2.414	2.593	93.1	Rt.
2	0+240	6.3	2.389	2.593	92.1	CL.
3	0+320	5.8	2.412	2.593	93.0	Lt.
4	0+400	5.0	2.391	2.593	92.2	Rt.
5	0+480	5.5	2.411	2.593	93.0	CL.
6	0+560	5.2	2.417	2.593	93.2	Lt.
				Average	92.768	
				Coeff. Of Var.	0.00522	

Also the other trial sections (Marshall Basalt & Marshal Basalt with PMA) were tested and sample results for Marshall Basalt section are tabulated in Table 17.

TABLE 17: FIELD DENSITY AND ASPHALT THICKNESS – LEFT DETOUR (MARSHAL BASALT)

SPECIMEN NO.	STATION K.M	THICKNESS (CM)	SPECIMEN BULK DENSITY (G / CM3)	THEORETICAL MAX. SPECIFIC GRAVITY (GMM)	% Gmm	NOTE
1	0+640	5.8	2.425	2.607	0.930	Lt.
2	0+720	6.2	2.436	2.607	0.934	CL.
3	0+800	5.2	2.418	2.607	0.928	Rt.
4	0+880	5.2	2.432	2.607	0.933	Lt.
5	0+960	5.3	2.395	2.607	0.919	CL.
6	1+040	4.9	2.425	2.607	0.930	Rt.
				Average	0.929	
				Coeff. Of Var.	0.00595	

The core results show that the required degree of compaction was achieved for the SUPERPAVE trail section with 92.7% average compaction (i.e. 7.3% initial air voids), which conforms to SUPERPAVE criteria.

V. Conclusions and Recommendations

5. 1 Implementation of SUPERPAVE in Jordan

SUPERPAVE Technology is anticipated to be implemented in Jordan in the near future. Many steps were taken in this direction, and to join all efforts together, the Ministry of Public Works and Housing (MPWH) announced in the year of 2010 the establishment of Asphalt Technology Committee (ATC) in order to supplement the information required for MPWH as a way to come up with a suitable decision concerning the implementation of Superpave for road construction / rehabilitation in Jordan.

As stated earlier, the first SUPERPAVE trial section was a part of this study using 19mm Basalt Wearing Course in Queen Alia International Airport (QAIA) road. The same mix design will be used for the main road according to construction schedule. Other trial sections will be constructed in Irbid Ring Road (IRR) by Jordan University of Science and Technology (JUST) researchers in the future.

In order to fully implement the technology of SUPERPAVE in Jordan; the following measures should be taken into consideration:

1. Bitumen Performance Grade:

   The bitumen performance grade map for Jordan was introduced by ASI [11] with reliability of 98%. PG64-10 bitumen is required for most areas in Jordan, and using modifiers can enhance the performance grade to consider any changes or revisions of the bitumen performance grade map and any upgrade might be needed due to heavy or slow traffic. The bitumen produced by Jordan Petroleum Refinery (JPR), having a penetration grade of 60/70,

was tested by ASI [11] and Khateeb [3] and was found to satisfy PG64-10 but lacks consistency and needs high quality control. Since JPR import raw material from different resources as Saudi Arabia and Iraq, this will affect the stability of the resulting bitumen performance grade. The MPWH shall specify the used bitumen performance grade for its project, and therefore; the JPR need to implement Quality Control and Quality Assurance policy to test and label their production of bitumen in terms of performance grade and not by penetration.

2. Facilities and Education

   a. It is necessary to train the current technicians on the new design technology. Training shall start from Jordanian Universities and Ministry of Public Works and Housing (MPWH) laboratories. Only two Jordanian universities have established their SUPERPAVE laboratory, namely JUST and Hashemite University.

   b. Jordan universities, in collaboration with the Ministry of Higher Education should drop Marshall design method from their course work and replace it with SUPERPAVE technology simply because they are based on AASHTO that had already dropped Marshall for its drawbacks since 1998[11]. Again, universities shall replace existing Marshall Laboratories with SUPERPAVE equipments.

   c. MPWH asphalt research lab has the SUPERPAVE Gyratory Compactor (SGC), Corelok and NCAT but no binder or performance testing equipment. Also, no private sector entity has any of SUPERPAVE equipments in their laboratory yet. This is because they do not have separate budget for the scientific research. The MPWH

will need to issue new specifications that include the SUPERPAVE technology in addition to the Marshall method until SUPERPAVE is fully implemented in Jordan. This will alarm the private sector to seriously consider establishing SUPERPAVE laboratories. Also MPWH need to upgrade the existing asphalt research laboratory with all required SUPERPAVE binder and performance testing equipments.

3. Immediate Mitigations

MPWH and Greater Amman Municipality (GAM) are the major authorities in charge of asphalt projects in Jordan. Therefore, till the full implementation of SUPERPAVE technology in Jordan, the following mitigations shall be included in the current specifications:

a. Start using %Gmm as the indicator of field density instead of Marshall daily density.

b. Specifying the bitumen performance grade for the new projects, and prohibit the use of ungraded bitumen.

c. Include SUPERPAVE technology in the “Specifications for Highway and Bridge Construction” [13] in addition to Marshall method till the full implementation of SUPERPAVE technology is completed.

4. Experimentation

   Universities and MPWH shall encourage the researchers to build trial sections for the SUPERPAVE technology within the projects under construction. Such trial sections will be very helpful to determine the suitability of the SUPERPAVE technology in Jordan when monitored and documented during their service life.

5. 2 Findings

The main objective of this study was to investigate the suitability of using SUPERPAVE technology in Jordan. This was achieved by evaluating the ability of currently used design method (Marshall) to predict the field densification through studying arterial road in Amman (QAIA road). Marshall compacted specimens failed to simulate field densification. SUPERPAVE specimens better simulated field densification. The aggregate degradation due to mixing, handling, and compaction has a significant effect on the pavement performance since it changes the original properties of the aggregate and consequently changes the mix.

Based on the given analysis of this study; the following findings can be drawn:

1. The Marshall method simulates the initial field compaction conditions and selects the optimum bitumen content based on this initial stage without considering the changes in the asphalt mix volumetric properties during trafficking. On the contrary, the SUPERPAVE mix design is based upon design life criteria, considering all changes in asphalt mix volumetric.

2. The required bitumen content for SUPERPAVE mix design was less than the required content for Marshall Mix design in case of limestone aggregate. However it was found to be slightly more in case of Basalt aggregate. This is

true for the investigated mixes only. Further researches are needed to generalize this statement.

3. Local aggregates (limestone) suffer severe degradation due to trafficking. This will increase the surface area and reduce the air voids. Accordingly, the use of Basalt may help in this regard. Also a new design method shall be adopted locally that can better simulate the field densification, the aggregate degradation, the air voids percentage drop, and the optimum bitumen content.

4. Implementation of SUPERPAVE in Jordan does not need special construction equipment. Therefore, this will not increase the construction cost on the client. The contractor of the trial section was able to meet the required field compaction criteria of the SUPERPAVE without additional effort.

5. Implementation of SUPERPAVE technology in Jordan will not raise a problem with the available bitumen produced by Jordan petroleum refinery (JPR) since the required performance grade for most of Jordan areas is PG64-10 which meets grade 60/70 that is commonly produced by JPR. In case higher performance grade is needed, a suitable bitumen modifier can be used to achieve the desired performance grade.

6. The Mix design of SUPERPAVE using local materials, laboratories and technician, and successful construction of the test section by local contractor prove the feasibility of SUPERPAVE Implementation in Jordan.

The SUPERPAVE trial section was constructed in QAIA road. The section is a step in the direction of SUPERPAVE implementation in Jordan. Construction of other trial sections is recommended in order to test SUPERPAVE pavement performance, and to

check the suitability of different asphalt modifiers (polymers) in enhancing the asphalt concrete pavement performance.

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APPENDIX

A. Aggregate Degradation calculations

B. 19mm SUPERPAVE HMA design for Limestone Wearing Course

C. 19mm SUPERPAVE HMA design for Limestone Binder Course

D. 19mm SUPERPAVE HMA design for Basalt Wearing Course

Aggregate Degradation calculations

APPENDIX –A

Table A1: Original Job Mix Formula parameters

Sieve Size (in)	Surface Area Factor cm^2/gm	Wearing JMF		Binder JMF	
		% Passing	Surface Area	% Passing	Surface Area
1”		100.00		100.00	
¾”	1.62	100.00	1.62	97.00	1.57
½”	2.29	85.10	1.95	77.00	1.76
3/8”	4.10	67.10	2.75	63.00	2.58
#4	6.40	45.60	2.92	42.00	2.69
#8	11.47	27.40	3.14	25.00	2.87
#20	26.00	14.70	3.82	14.00	3.64
#50	82.50	9.10	7.51	8.00	6.60
#80	180.00	7.00	12.60	7.00	12.60
#200	615.00	5.50	33.83	5.10	31.37
Total Surface Area (cm2/gm)			70.13		65.68
Fineness Modulus (FM)		3.96		4.04	
Fine Aggregate %		40.10		36.90	
Filler %		5.50		5.10	

Table A2: Marshall compacted specimens parameters

Sieve Size (in)	**Surface Area Factor cm^2/gm**	**Wearing**		**Binder**	
		% Pass	S.A	% Pass	S.A
1”		100.00		100.00	
¾”	1.62	100.00	1.62	98.11	1.59
½”	2.29	88.54	2.03	85.72	1.96
3/8”	4.10	77.49	3.18	72.98	2.99
#4	6.40	46.96	3.01	44.99	2.88
#8	11.47	28.65	3.29	26.34	3.02
#20	26.00	15.81	4.11	15.79	4.10
#50	82.50	10.44	8.61	11.20	9.24
#80	180.00	8.02	14.44	9.18	16.52
#200	615.00	5.68	34.91	**6.98**	42.93
Total Surface Area (cm2/gm)			75.19		85.24
Fineness Modulus (FM)		3.90		3.92	
Fine Aggregate %		41.28		38.01	
Filler %		5.68		6.98	
Surface Area Increase %			7.2%		29.8%
FM decrease %		1.5%		2.8%	
Fine Aggregate Increase %		2.9%		3.0%	
Filler Increase %		3.2%		36.9%	

Table A3: SUPERPAVE compacted specimen parameters

Sieve Size (in)	**Surface Area Factor cm^2/gm**	**Wearing**		**Binder**	
		% Pass	S.A	% Pass	S.A
1”		100.00		100.00	
¾”	1.62	100.00	1.62	98.03	1.59
½”	2.29	88.51	2.03	77.21	1.77
3/8”	4.10	76.45	3.13	61.65	2.53
#4	6.40	58.47	3.74	55.00	3.52
#8	11.47	36.32	4.16	32.32	3.71
#20	26.00	24.60	6.39	22.20	5.77
#50	82.50	18.87	15.57	16.65	13.74
#80	180.00	16.73	30.12	14.56	26.21
#200	615.00	**13.88**	85.36	**11.86**	72.93
Total Surface Area (cm2/gm)			152.13		131.75
Fineness Modulus (FM)		3.45		3.59	
Fine Aggregate %		44.59		43.14	
Filler %		13.88		11.86	
Surface Area Increase %			116.9%		100.6%
FM decrease %		12.9%		11.1%	
Fine Aggregate Increase %		11.2%		16.9%	
Filler Increase %		152.4%		132.5%	

Table A4: Field compacted wearing – right carriageway parameters

Sieve Size (in)	Surface Area Factor cm^2/gm	Rt. Side*		Lt. Side*	
		% Pass	S.A	% Pass	S.A
1”		100.00		100	
¾”	1.62	100.00	1.62	100	1.62
½”	2.29	89.10	2.04	85.5	1.96
3/8”	4.10	78.80	3.23	74.68	3.06
#4	6.40	50.90	3.26	48.6	3.11
#8	11.47	31.40	3.60	30.6	3.51
#20	26.00	17.98	4.67	19.56	5.09
#50	82.50	10.33	8.52	13.9	11.47
#80	180.00	8.98	16.16	11	19.80
#200	615.00	**6.70**	41.21	**7.18**	44.16
Total Surface Area (cm2/gm)			84.32		93.77
Fineness Modulus (FM)		3.80		3.76	
Fine Aggregate %		44.20		41.42	
Filler %		6.70		7.18	
Surface Area Increase %			20.2%		33.7%
FM decrease %		4.0%		5.0%	
Fine Aggregate Increase %		10.2%		3.3%	
Filler Increase %		21.8%		30.5%	

* Average results were considered

Table A5: Field compacted wearing – Left carriageway parameters

Sieve Size (in)	**Surface Area Factor cm^2/gm**	**Rt. Side***		**Lt. Side***	
		% Pass	S.A	% Pass	S.A
1”		100.00		100.00	
¾”	1.62	99.00	1.60	100.00	1.62
½”	2.29	89.00	2.04	81.00	1.85
3/8”	4.10	76.00	3.12	68.00	2.79
#4	6.40	50.00	3.20	46.00	2.94
#8	11.47	29.00	3.33	31.00	3.55
#20	26.00	16.00	4.16	19.00	4.94
#50	82.50	11.10	9.16	12.20	10.07
#80	180.00	9.90	17.82	10.90	19.62
#200	615.00	**7.00**	43.05	**7.47**	45.94
Total Surface Area (cm2/gm)			87.47		93.33
Fineness Modulus (FM)		3.84		3.81	
Fine Aggregate %		43.00		38.53	
Filler %		7.00		7.47	
Surface Area Increase %			33.2%		33.1%
FM decrease %		5.0%		3.9%	
Fine Aggregate Increase %		16.5%		-3.9%	
Filler Increase %		37.3%		35.8%	

* Average results were considered

Table A6: Field compacted binder course – shoulder parameters

Sieve Size (in)	**Surface Area Factor cm²/gm**	**Rt. Side***		**Lt. Side***	
		% Pass	S.A	% Pass	S.A
1”		100.00		100.00	
¾”	1.62	97.10	1.57	99.00	1.60
½”	2.29	73.90	1.69	89.00	2.04
3/8”	4.10	61.40	2.52	76.00	3.12
#4	6.40	43.00	2.75	50.00	3.20
#8	11.47	28.00	3.21	29.00	3.33
#20	26.00	16.50	4.29	16.00	4.16
#50	82.50	10.78	8.89	11.10	9.16
#80	180.00	9.50	17.10	9.90	17.82
#200	615.00	**7.31**	44.96	**7.00**	43.05
Total Surface Area (cm2/gm)			86.99		87.47
Fineness Modulus (FM)		3.92		3.84	
Fine Aggregate %		35.69		43.00	
Filler %		7.31		7.00	
Surface Area Increase %			32.4%		33.2%
FM decrease %		2.9%		5.0%	
Fine Aggregate Increase %		-3.3%		16.5%	
Filler Increase %		43.3%		37.3%	

* Average results were considered

Table A7: Field compacted binder course – Right carriageway parameters

Sieve Size (in)	**Surface Area Factor cm^2/gm**	**Rt. Side***		**Lt. Side***	
		% Pass	S.A	% Pass	S.A
1”		100.00		100.00	
¾”	1.62	99.00	1.60	100.00	1.62
½”	2.29	84.00	1.92	79.00	1.81
3/8”	4.10	71.00	2.91	68.00	2.79
#4	6.40	48.70	3.12	47.00	3.01
#8	11.47	29.00	3.33	31.00	3.55
#20	26.00	17.10	4.45	18.70	4.86
#50	82.50	11.00	9.08	12.00	9.90
#80	180.00	8.89	16.00	10.80	19.44
#200	615.00	**7.00**	43.05	**7.28**	44.77
Total Surface Area (cm2/gm)			85.45		91.75
Fineness Modulus (FM)		3.85		3.81	
Fine Aggregate %		41.70		39.72	
Filler %		7.00		7.28	
Surface Area Increase %			30.1%		39.7%
FM decrease %		4.6%		5.8%	
Fine Aggregate Increase %		13.0%		7.6%	
Filler Increase %		37.3%		42.7%	

* Average results were considered

APPENDIX –B

Table B1: Aggregate Blend Analysis

Aggregate Blend Analysis										
Project:	ADC-I			Spec.	ASTM			Date:	8-Aug-09	
Location:	Amman			TH#:	50 mm					
Mix Type:	19mm Superpave	WEARING COURSE								
	%	Aggregate Description						Legal Description		
1	0	#1 Wearing Course at 1+300 Lt.						L2-1		
2	0	#2 Wearing Course at 1+000 Rt						R1		
3	0	#3 Wearing Course at 1+140 Lt						L1		
4	100	JMF								
Aggregate		1	2	3	4	5	6		Blend	
%Aggregate		0	0	0	0	100			MAS	
Sieve Size	mm	Percent Passing							NMAS	
1 1/2"	37.5	100	100	100		100		1	100.0	
1"	25	100	100	100		100		2	100.0	MAS
3/4"	19	100	100	100		100		NMAS	100.0	
1/2"	12.5	81	85	87		85.1		4	85.1	
3/8"	9.5	65	71	72		67.1		5	67.1	
#4	4.75	39	43	44		45.6		6	45.6	
#8	2.36	21	25	23		27.4		7	27.4	
#20	1.18	12	14	12		14.7		8	14.7	
#50	0.6	8	9	7		9.1		9	9.1	
#80	0.3	7	7	6		7		10	7.0	
#200	0.075	5.4	5.5	4.5		5.5		11	5.5	
	Gsb					2.486			2.486	
	AC Content:	5.10%								
									NMAS	**19.0**
	Asphalt Source:	ARAMCO			Grade:	PG 64-10				

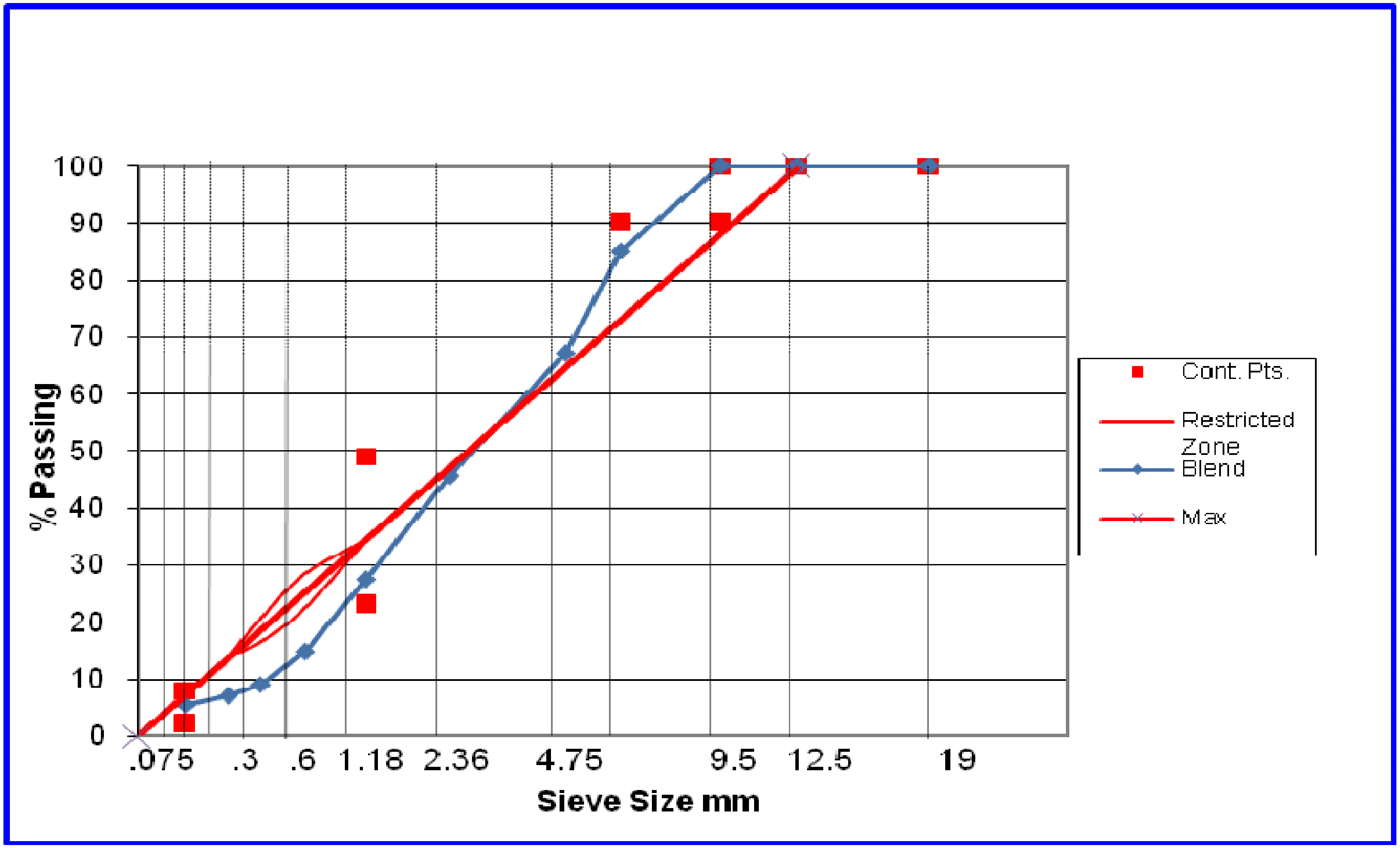

Figure *B1: Gradation* Chart

Table B2: Measured Specific Gravity Analysis

Measured Specific Gravity Analysis

Project: ADC-I

Spec.

Gmm

Sp. Gravity of AC:

Mix	W3		W1		W2	
%AC	5.6		5.1		4.6	
	W31	W32	W11	W12	W21	W22
Wt. Dry Mix						
Wt. Container+H2O						
Wt. Container+H2O+Mix						
Max Sp. Gravity, Gmm	2.350	2.380	2.390	2.405	2.460	2.462
Avg. Max Gravity	2.365		2.398		2.461	

Gmb(meas)

Mixing Temp. ℃: 160

Compaction Temp. ℃: 150

Mix	W3		W1		W2	
%AC	5.6		5.1		4.6	
	W31	W32	W11	W12	W21	W22
Spec. Wt. in Air	4780	4788.8	4734.9	4755.5	4760.2	4733.4
Spec. Wt. In H2O	2722.6	2751.5	2705.6	2733.9	2729.2	2715.5
SSD	4788.1	4791.2	4741.7	4762.3	4772	4745.5
Bulk Sp. Gravity, Gmb	2.314	2.348	2.325	2.344	2.330	2.332
Av. Bulk Sp. Gravity	2.331		2.335		2.331	

Table B3: Sample Single Specimen Analysis

Sample Single Specimen Analysis

			Specimen	1
			Nini =	8
			Ndes =	100
	Test ID=	**W31**		
	File Name=			
	Test Angle=	1.25		
	Test Pressure=	600		
	Start Date=	8-Aug-09		
	Start Time=	9:01:06		
	Test Mode=	CycleCount		
	Total Mass (g) =	4700		
	Gmb (meas) =	2.314		
	Gmm =	2.350		
Gyrations	Ht mm	Gmb (est.)	Gmb (corr.)	%Gmm
1	134.8	1.973	2.000	85.11
8	124.5	2.136	2.166	92.15
10	123.2	2.159	2.188	93.12
20	119.6	2.224	2.254	95.92
30	118.1	2.252	2.283	97.14
40	117.3	2.267	2.298	97.81
50	117	2.273	2.304	98.06
60	116.8	2.277	2.308	98.22
70	116.7	2.279	2.310	98.31
80	116.6	2.281	2.312	98.39
90	116.5	2.283	2.314	98.48
100	116.5	2.283	2.314	98.48

Summary

Specimen		%Gmm	% A V
Nini =	8	92.15	7.85
Ndes =	100	98.48	1.52

Volume Analysis @ Ndes

Gsb =	2.486	%VMA=	12.12
Ps =	94.4	%VFA=	87.43
Pb=	5.6		

Table B4: Compaction Properties

Summary of Compaction Properties at Different Asphalt Contents

Average Compaction

Cycles	W3	W1	W2
8.0	92.229	86.911	84.347
10.0	93.202	88.019	85.319
20.0	96.007	91.410	88.470
30.0	97.227	93.359	90.480
40.0	97.890	94.600	91.748
50.0	98.141	95.432	92.626
60.0	98.309	96.036	93.286
70.0	98.393	96.524	93.798
80.0	98.477	96.894	94.155
90.0	98.562	97.142	94.404
100.0	98.562	97.391	94.717

Compaction Properties

AC Trial	%AC	%Gmm @Nini	%Gmm @Ndes
B3	5.6	92.23	98.56
B1	5.1	86.91	97.39
B2	4.6	84.35	94.72

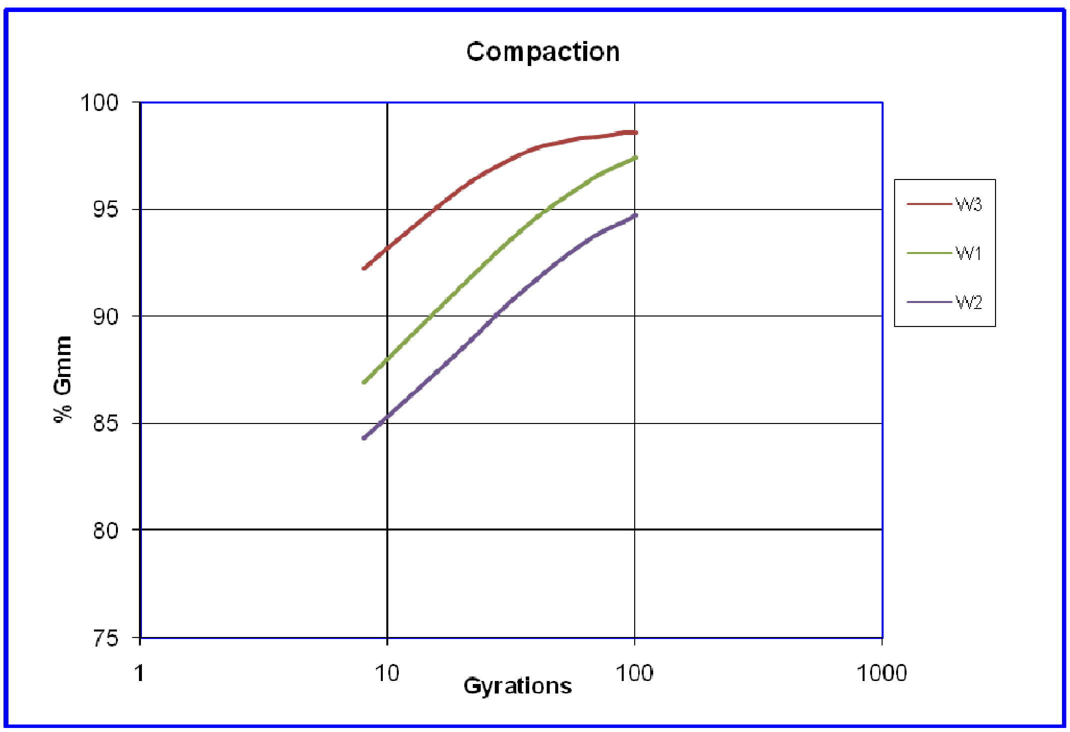

Figure B5: Compaction Chart

Table B6: Volumetric Properties at Ndes

%AC	%Air Voids	%VMA	%VFA	Optimum Ac (%)
5.6	1.4	11.48	87.5	**4.840**
5.1	2.6	10.86	76.0	
4.6	5.3	10.54	49.9	

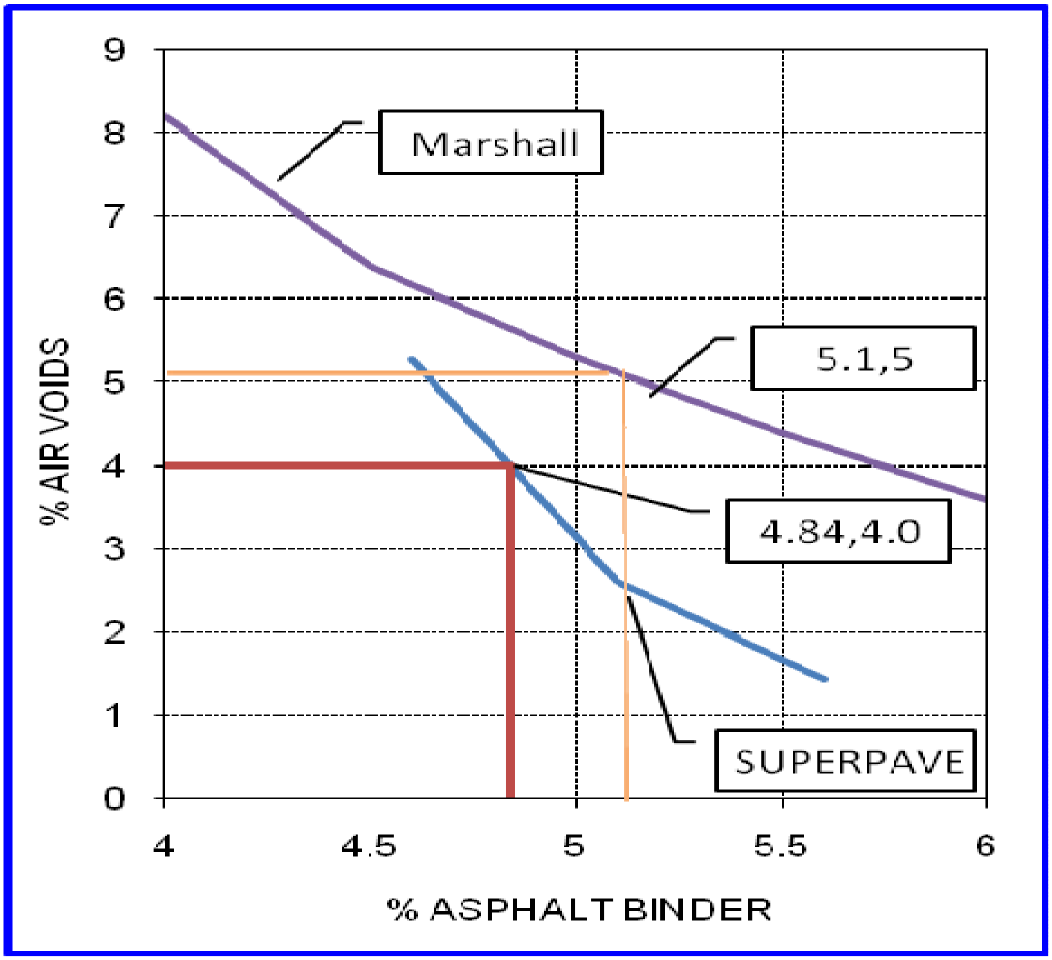

FIGURE5 B3: Optimum Binder Content Selection

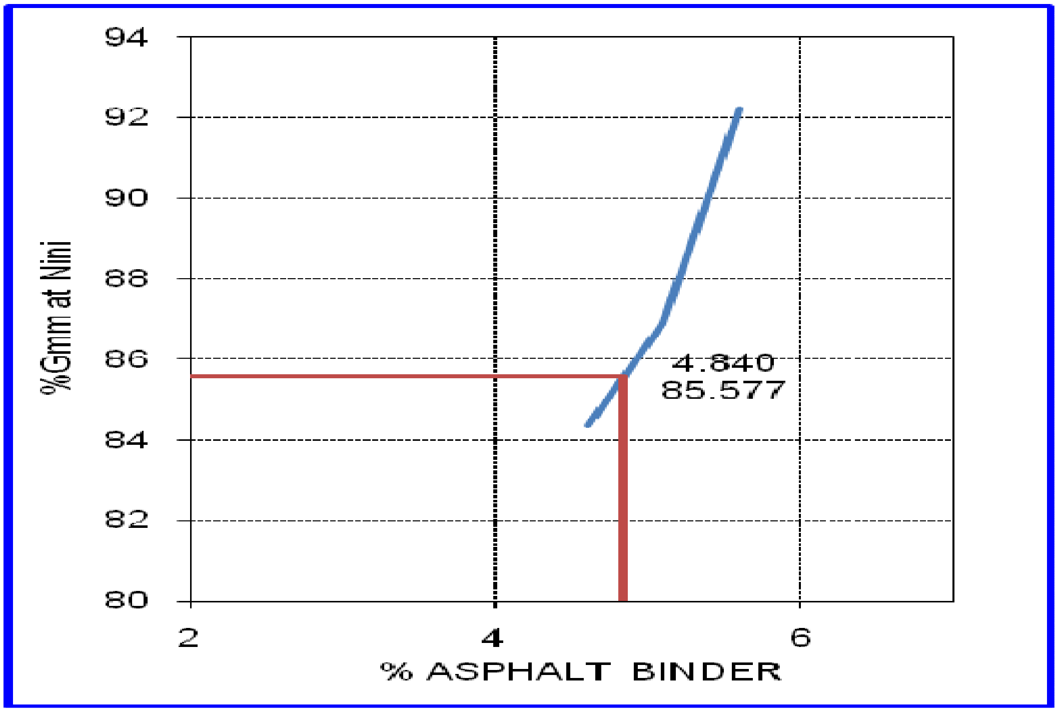

FIGURE B4: %Gmm Vs %Asphalt Binder

APPENDIX –C

19mm SUPERPAVE HMA design for Limestone Binder Course

Table C1: Aggregate Blend Analysis

Aggregate Blend Analysis

Project:	ADC-I	Spec.	ASTM	Date:	9-Aug-09
Location:	Amman	TH#:	70 mm		
Mix Type:	19mm Superpave	BINDER COURSE			

	%	Aggregate Description	Legal Description
1	0	#1 Binder Course at OP2+200 SHI	
2	0	#2 Binder Course at 2+780 Rt-CW3	R2-2
3	0	#3 Binder Course at (0+540 to 2+000) Lt	L2-2
4	0	#4 Stone	
5	100	JMF	
6			

Aggregate		1	2	3	4	5	6		Blend	
%Aggregate		0	0	0	0	100			MAS	
Sieve Size	mm	Percent Passing							NMAS	
1 1/2"	37.5	100	100	100		100		1	100.0	1
1"	25	100	100	100		100		2	100.0	MAS
3/4"	19	97	97	99		97		NMAS	97.0	3
1/2"	12.5	81	76	81		77		4	77.0	4
3/8"	9.5	66	58	63		63		5	63.0	5
#4	4.75	42	37	39		42		6	42.0	6
#8	2.36	24	22	26		25		7	25.0	7
#20	1.18	12	13	14		14		8	14.0	8
#50	0.6	8	9	9		8		9	8.0	9
#80	0.3	6	7	7		7		10	7.0	10
#200	0.075	4.5	5.6	4.8		5.1		11	5.1	11
	Gsb					2.492			2.486	

AC Content:	4.90%	NMAS	**19.0**
Asphalt Source:	ARAMCO	Grade:	PG 64-10

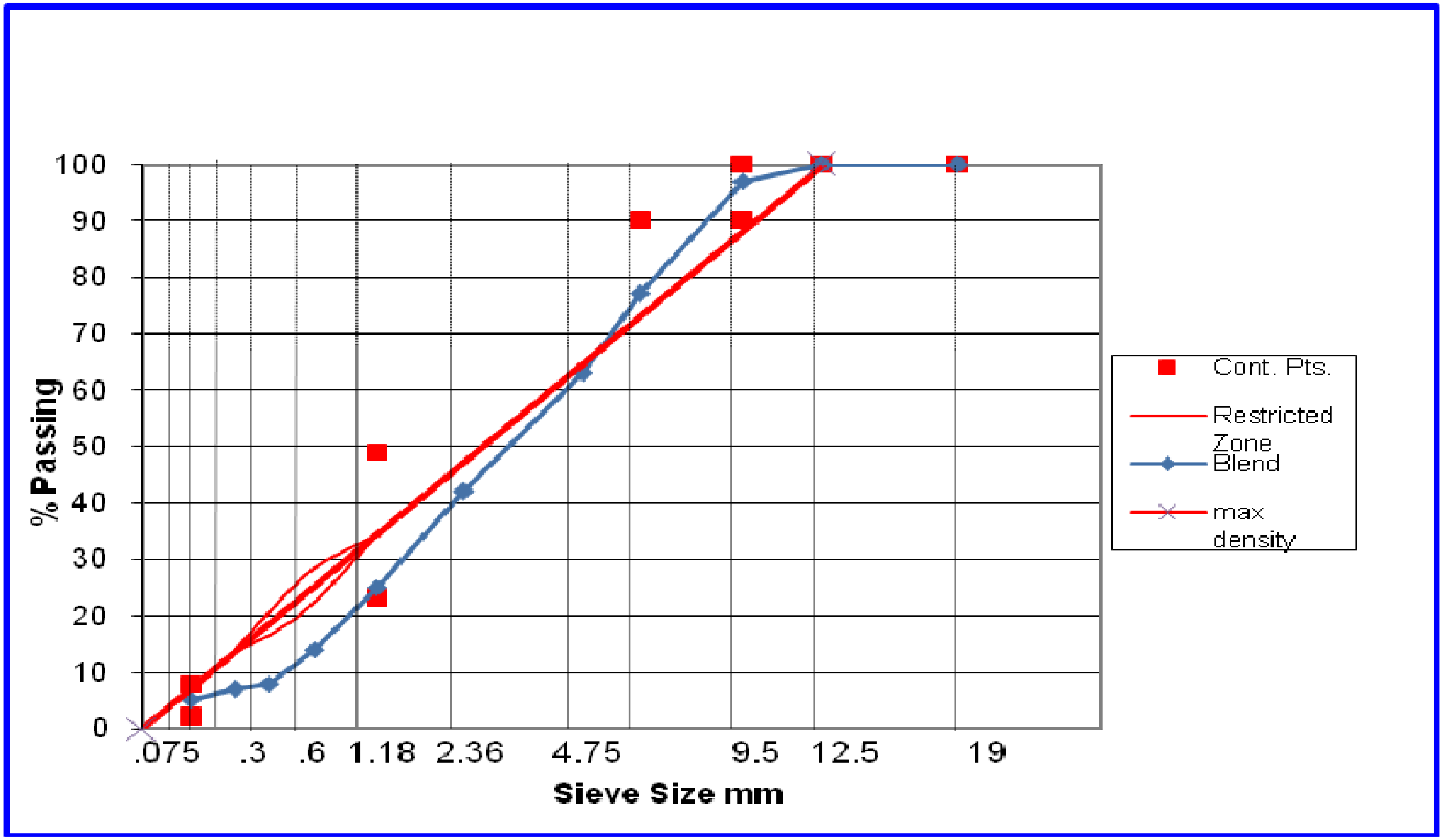

Figure C1: Gradation Chart

Table C2: Measured Specific Gravity Analysis

Measured Specific Gravity Analysis

Project: ADC-I

Spec.

Gmm

Sp. Gravity of AC:

Mix	B3		B1		B2	
%AC	5.4		4.9		4.4	
	B31	B32	B11	B12	B21	B22
Wt. Dry Mix						
Wt. Container+H2O						
Wt. Container+H2O+Mix						
Max Sp. Gravity, Gmm	2.390	2.387	2.392	2.415	2.435	2.433
Avg. Max Gravity	2.389		2.404		2.434	

Gmb(meas)

Mixing Temp. ℃: 160 | Compaction Temp. ℃: 150

Mix	B3		B1		B2	
%AC	5.4		4.9		4.4	
	B31	B33	B11	B12	B21	B22
Spec. Wt. in Air	4789.5	4538.2	4726.1	4756.4	4700	4703.5
Spec. Wt. In H2O	2743.7	2594.8	2685.9	2723.6	2686	2699
SSD	4795.7	4539.3	4738.1	4762.9	4713.1	4728.9
Bulk Sp. Gravity, Gmb	2.334	2.334	2.303	2.332	2.319	2.317
Av. Bulk Sp. Gravity	2.334		2.318		2.318	

Table C3: Measured Specific Gravity Analysis

Sample Single Specimen Analysis				
			Specimen	1
			Nini =	8
			Ndes =	100
	Test ID=	**B31**		
	File Name=			
	Test Angle=	1.25		
	Test Pressure=	600		
	Start Date=	Aug-09		
	Start Time=	9:00:27		
	Test Mode=	CycleCount		
	Total Mass (g) =	4700		
	Gmb (meas) =	2.334		
	Gmm =	2.390		
Gyrations	Ht mm	Gmb (est.)	Gmb (corr.)	%Gmm
1	138.6	1.919	1.979	82.79
8	127.9	2.079	2.144	89.72
10	126.5	2.102	2.168	90.71
20	122.7	2.168	2.235	93.52
30	120.8	2.202	2.270	94.99
40	119.6	2.224	2.293	95.94
50	118.9	2.237	2.307	96.51
60	118.4	2.246	2.316	96.92
70	118	2.254	2.324	97.25
80	117.8	2.258	2.328	97.41
90	117.6	2.262	2.332	97.58
100	117.5	2.264	2.334	97.66

Summary

Specimen		%Gmm	% A V
Nini =	8	89.72	10.28
Ndes =	100	97.66	2.34

Volume Analysis @ Ndes

Gsb =	2.486	%VMA=	11.19
Ps =	94.6	%VFA=	79.08
Pb=	5.4		

Table C4: Summary of Compaction Properties at Different Asphalt Contents

Summary of Compaction Properties at Different Asphalt Contents

Average Compaction

Cycles	B3	B1	B2
8.0	89.666	88.918	84.664
10.0	90.671	89.547	85.673
20.0	93.518	91.641	88.850
30.0	95.010	92.972	90.694
40.0	95.977	93.875	91.928
50.0	96.550	94.599	92.847
60.0	96.963	95.094	93.549
70.0	97.297	95.554	94.142
80.0	97.464	95.857	94.581
90.0	97.632	96.120	94.894
100.0	97.717	96.428	95.228

Compaction Properties

AC Trial	%AC	%Gmm @Nini	%Gmm @Ndes
B3	5.4	89.67	97.72
B1	4.9	88.92	96.43
B2	4.4	84.66	95.23

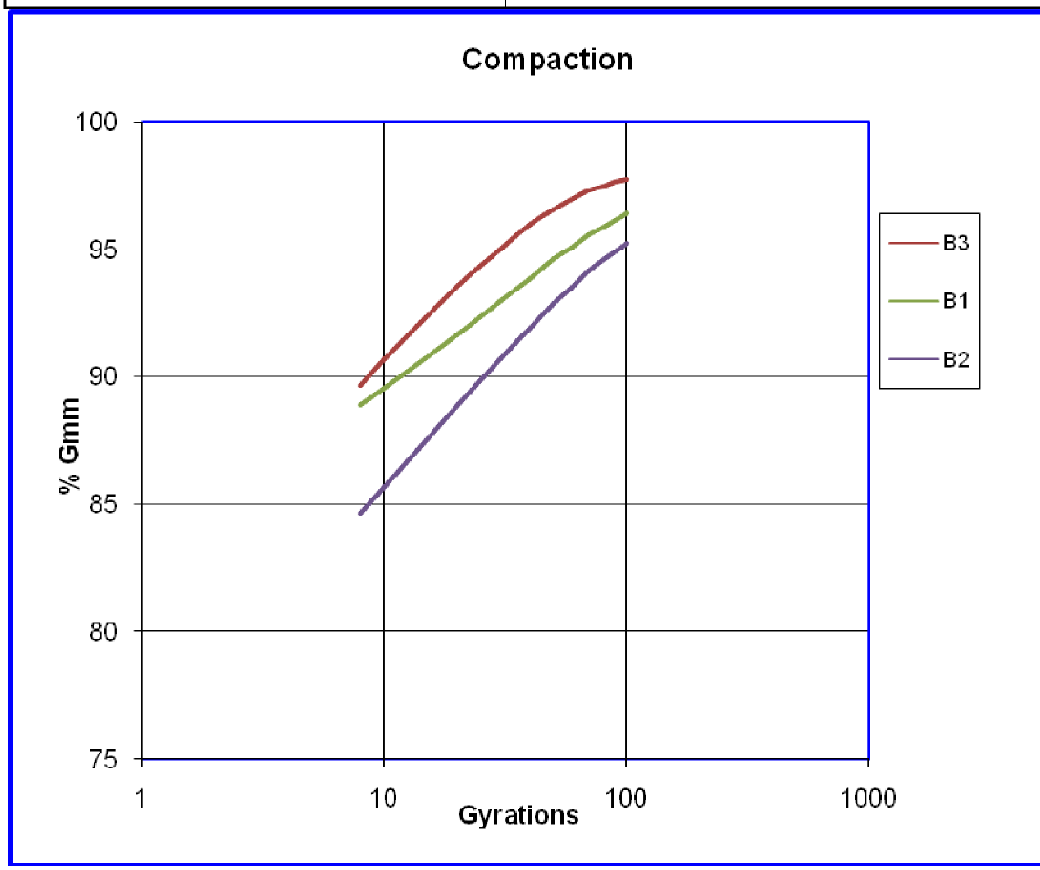

Figure C2: Compaction Chart

Table C5: Volumetric Properties at Ndes

Volumetric Properties at Ndes				
%AC	%Air Voids	%VMA	%VFA	Optimum Ac (%)
5.4	2.3	11.19	79.6	**4.722**
4.9	3.6	11.35	68.5	
4.4	4.8	10.87	56.1	

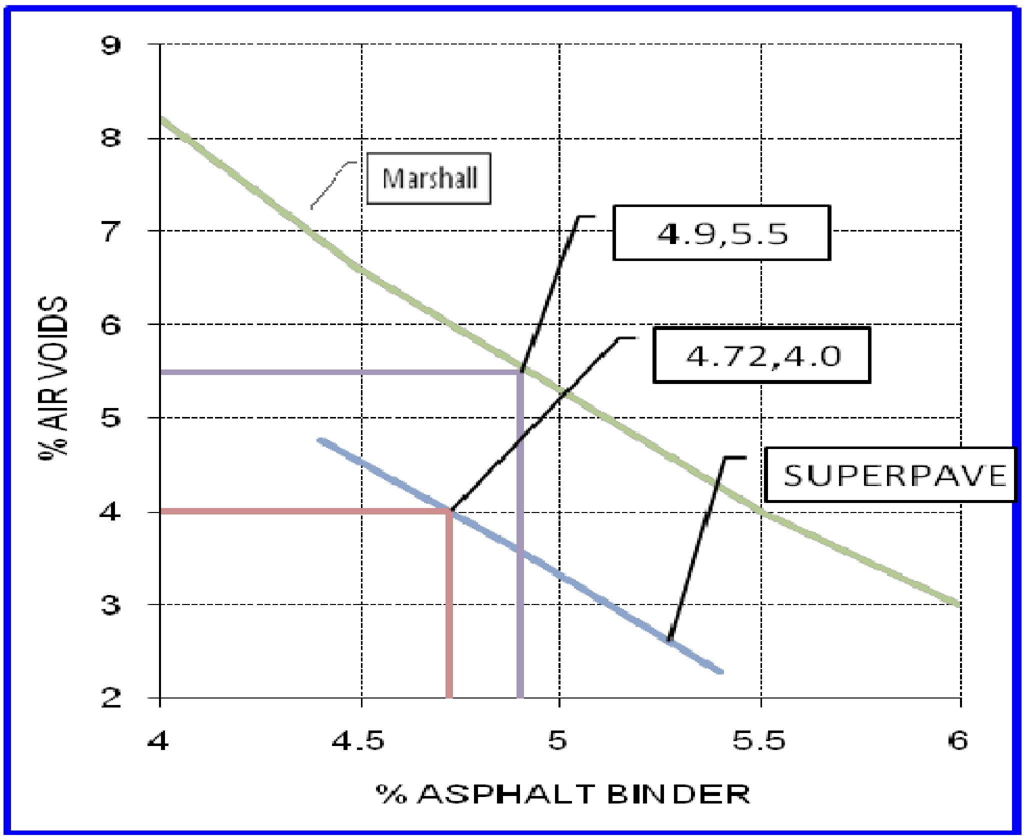

FIGURE C3: Optimum Binder Content Selection

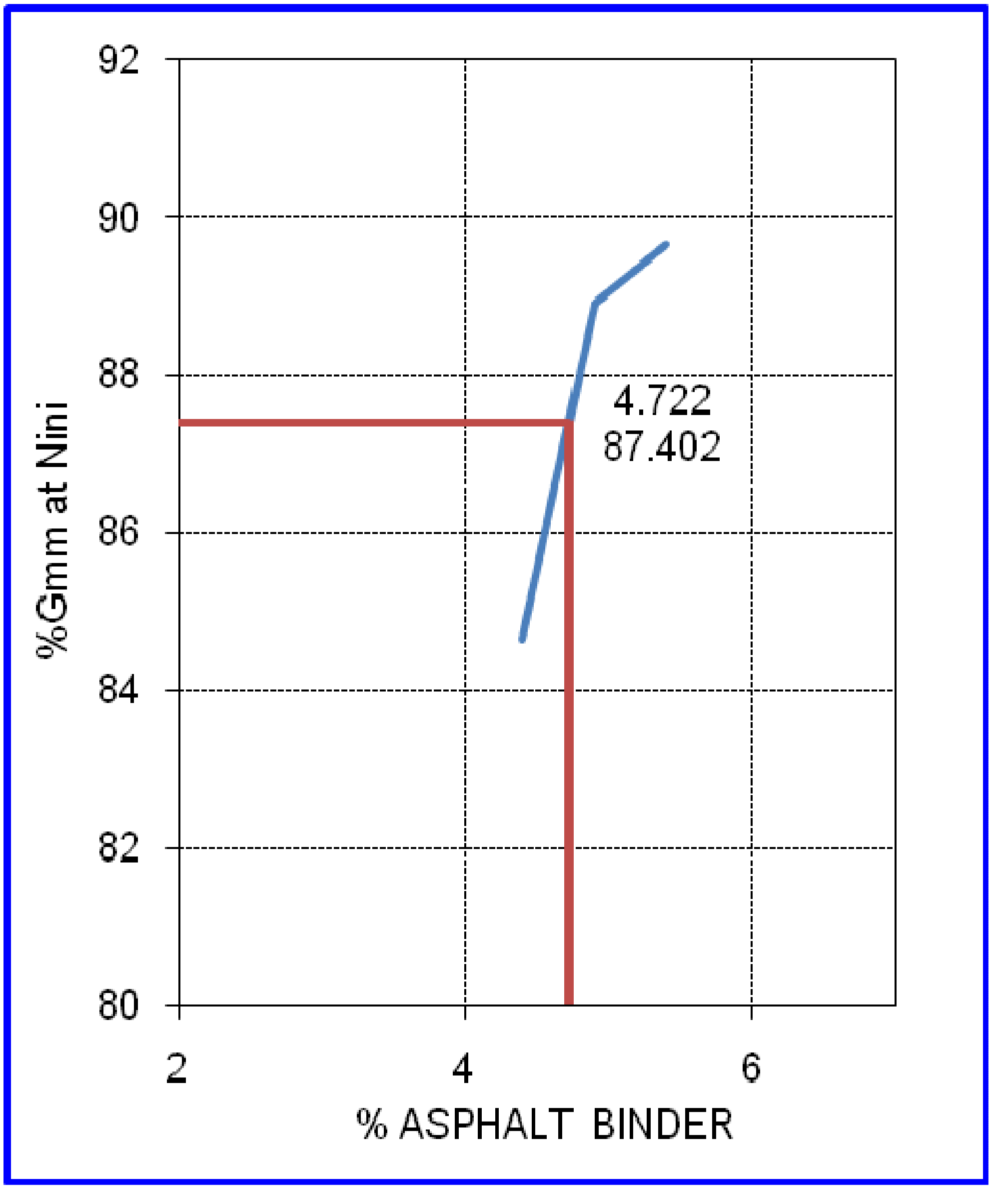

FIGURE C4: %Gmm Vs %Asphalt Binder

19mm SUPERPAVE HMA design for Basalt Wearing Course

APPENDIX –D

Table D1: Aggregate Blend Analysis

Aggregate Blend Analysis

Project:	QAIA Road	Spec.	ASTM	Date: 12-Mar-10
Location:	Airport Road	TH#:	50 mm	
Mix Type:	19mm Superpave	BASALT WEARING COURSE		

	%	Aggregate Description	Legal Description
1	29	#1 Coarse Agg. (Basalt)	Hot Bin No.1
2	36	#2 Medium Agg. (Basalt)	Hot Bin No.2
3	35	#3 Fine Agg. (Mixed: Basalt + Fine)	Hot Bin No.3
4	0		
5	0		
6			

Aggregate		1	2	3	4	5	6		Blend	
%Aggregate		29	36	35					MAS	
Sieve Size	mm	Percent Passing							NMAS	
1 1/2"	37.5	100	100	100				1	100.0	
1"	25	100	100	100				2	100.0	MAS
3/4"	19	100	100	100				NMAS	100.0	
1/2"	12.5	48	100	100				4	84.9	
3/8"	9.5	9	84	100				5	67.9	
#4	4.75	3	23	99				6	43.8	
#8	2.36	2	5	74				7	28.3	
#20	1.18	1	2	42				8	15.7	
#50	0.6	1	2	24				9	9.4	
#80	0.3	1	2	17				10	7.0	
#200	0.075	0.6	1.7	11.4				Q	4.8	
	Gsb	2.798	2.782	2.687					2.753	

AC Content:	**4.643%**		
		NMAS	**19.0**
Asphalt Source:	ARAMCO	Grade:	**PG 64-10**

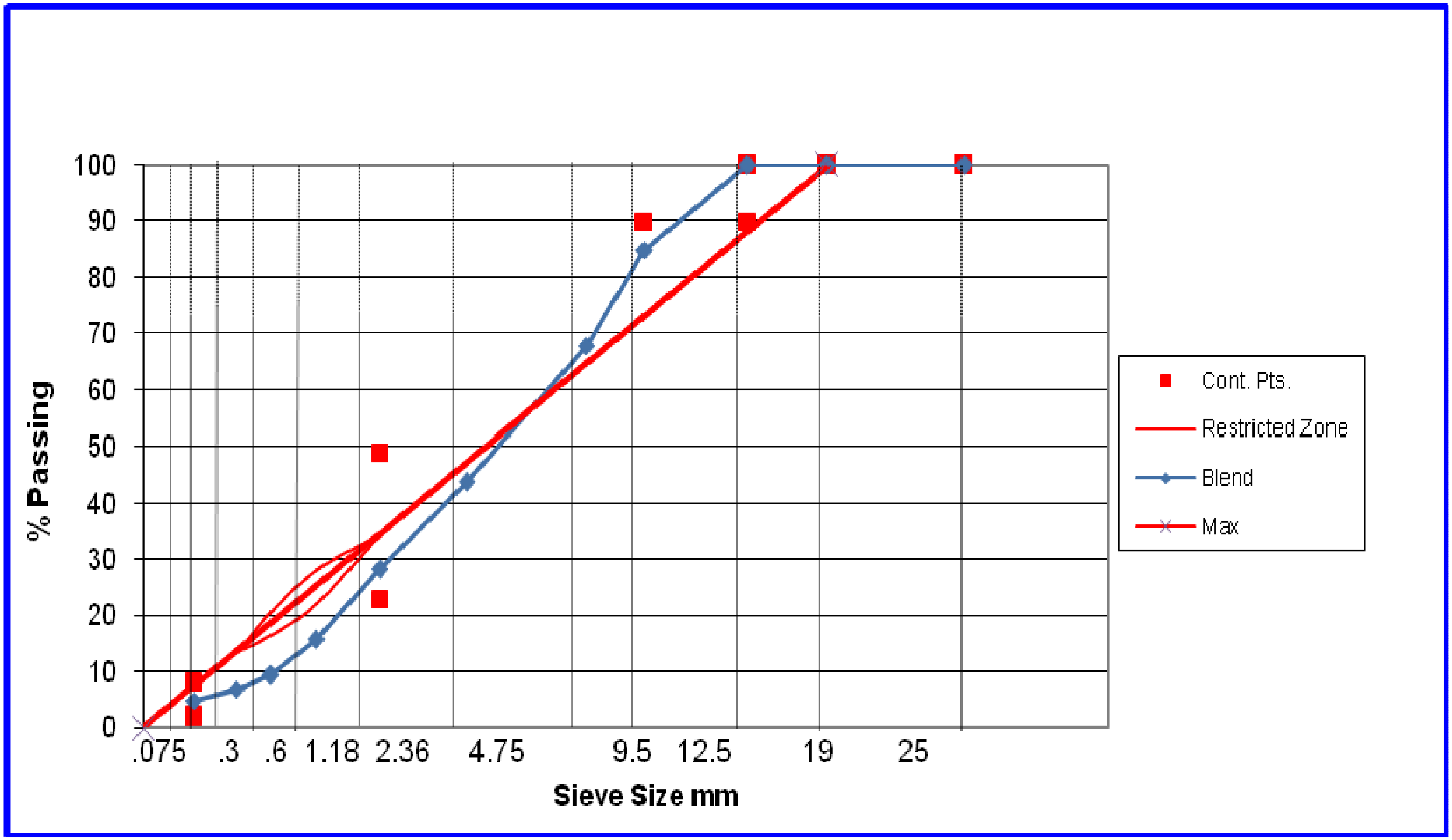

Figure D1: Gradation Chart

Table D2: Bulk Specific Gravity

Gmb = (A / (B - C)) * K						
	A	**B**	**C**	**ºC**	**G_{mb}**	**Corr. G_{mb}**
Sample #	**Dry Mass**	**SSD Mass**	**Mass in $H_2$0**		**(Ndes)**	**(Nini)**
Sample 1a	4640.2	4685.1	2774.1	25	2.428	2.209
Sample 1b	4676.4	4727.8	2790.6	25	2.414	2.191
Sample 1c				25		
Sample 2a	4673.2	4700.8	2821.2	25	2.486	2.247
Sample 2b	4717.0	4744.9	2840.3	25	2.477	2.244
Sample 2c	4677.3	4732.6	2815.4	25	2.440	2.245
Sample 3a	4715.4	4729.7	2837.8	25	2.492	2.247
Sample 3b	4710.8	4734.4	2831.2	25	2.475	2.230
Sample 3c	4726.0	4742.8	2839.4	25	2.483	2.270
Sample 4a	4704.3	4710.2	2837.6	25	2.512	2.260
Sample 4b						
Sample 4c	4725.9	4733.5	2839.8	25	2.496	2.277

Table D3: Compaction

Average Compaction %Gmm				
Cycles	1	2	3	4
8.0	83.262	85.671	86.533	87.987
10.0	84.135	86.513	87.380	88.882
20.0	86.471	88.888	89.927	90.768
30.0	87.817	90.279	91.379	92.904
40.0	88.751	91.216	92.427	93.944
50.0	89.512	91.970	93.213	94.736
60.0	90.053	92.555	93.856	95.429
70.0	90.522	93.070	94.406	95.931
80.0	90.916	93.461	94.854	96.404
90.0	91.314	93.827	95.226	96.801
100.0	91.635	94.145	95.549	97.122

Table D4: Volumetric

%AC	%Air Voids	%VMA	%VFA	Optimum Ac (%)
3.5	8.36	15.12	44.7	**4.643**
4	5.85	13.94	58.2	
4.5	4.45	13.84	67.9	
5	2.88	13.58	78.9	

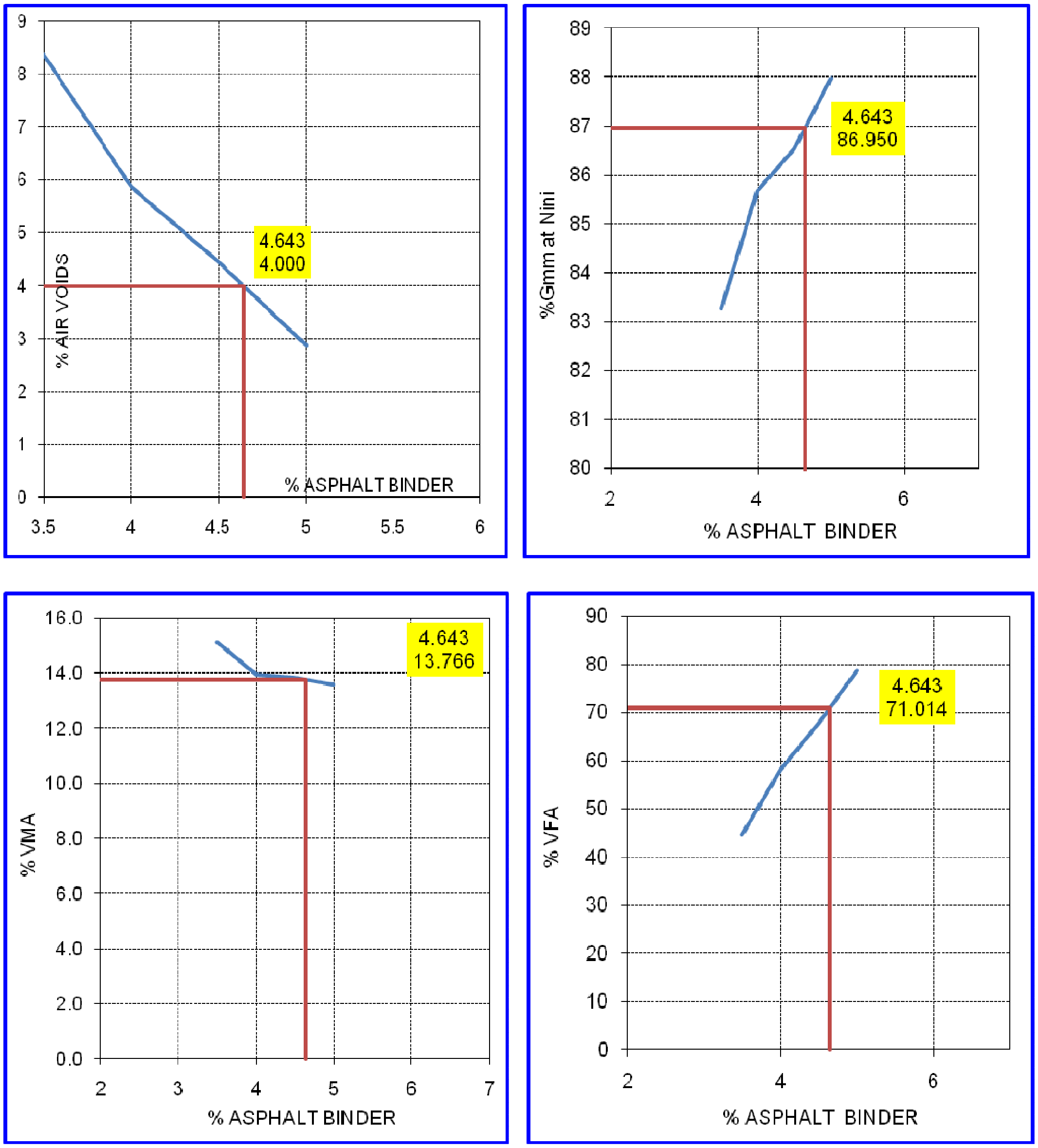

Figure D2: SUPERPAVE Design Charts

مدى ملائمة استخدام تكنولوجيا "السوبربيڤ" في الأردن

اعداد

محمد علي الصمادي

المشرف

الدكتور ليث طاشمان

الملخص

تهدف هذه الدراسة إلى المقارنة بين طريقة "مارشال" المستخدمة محلياً لأغراض تصميم الخلطات الأسفلتية وبين طريقة "السوبربيف" المستخدمة حالياً في الولايات المتحدة وبعض دول المنطقة كالمملكة العربية السعودية، وبالتالي بيان مدى ملائمة الأخيرة لنوع الحصمة المتوفرة محلياً بالاضافة إلى مدى ملائمة استخدام تكنولوجيا "السوبربيڤ" للضروف في الأردن.

تم قياس التفتت الحاصل بالعينات المحضرة بطريقتي "مارشال" و "السوبر بيڤ" ومقارنة النتائج بنتائج التفتت لعينات من الموقع. لغرض قياس التفتت تم اعتماد أربعة مؤشرات وهي: التغير بنسبة المار من منخل رقم ٢٠٠، والتغير بنسبة المواد الناعمة، والتغير بالمساحة السطحية للحصمة، والتغير بمعامل النعومة.

تم ملاحظة ازدياد مقدار التفتت الحاصل بالحصمة مع زيادة استخدام الطريق، وأن طريقة مارشال بالدمك لم تستطع التنبؤ بالتفتت الحاصل بالعينات الموقعية المعرضة لحركة السير منذ خمسة أعوام على خلاف طريقة "السوبر بيڤ" للدمك والتي أظهرت قدرة كبيرة على التنبؤ بسلوك الخلطة خلال تعرضها للأحمال المحورية خلال عمر الاستخدام.

تتعرض الحصمة المستخدمة محلياً بالخلطات الأسفلتية (الحجر الجيري) لتفتت كبير نتيجة الأحمال المرورية، وبالتالي زيادة المساحة السطحية ونقصان حجم الفراغات الهوائية بالخلطة الأسفلتية. لذلك لابد من تبني طريقة جديدة لديها القدرة على توقع التفتت بالحصمة والمتسبب بنقص الفراغات الهوائية وبالتالي حساب الجرعة المثالية للأسفلت اللازم لتماسك وديمومة الخلطة الأسفلتية. تقيِّم هذه الدراسة قدرة تكنولوجيا "السوبر بيڤ" في الأردن لتحقيق هذه التطلعات للمحافظة على العمر التصميمي للخلطة الأسفلتية.

من خلال هذه الدراسة تم العمل وبالتعاون مع وزارة الأشغال العامة والإسكان تم انشاء مقطع بحثي بطول ٥٠٠م بمشروع طريق مطار الملكة علياء الدولي باستخدام تكنولوجيا "السوبر بيڤ" بالاضافة لاستخدام حصمة البازلت. تم تنفيذ هذا المقطع البحثي لمساعدة الجهات المعنية في الأردن لأخذ قرار بتبني تكنولوجيا "السوبربيڤ" من خلال مراقبة تصرف المواقع المنفذة باستخدام تكنولوجيا "السوبربيڤ" والتأكد من مدى ملائمتها للضروف في الأردن.